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THE **BOEING** COMPANY

*Armed Group
Seattle, WA 98124*

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NUMBER DE-125911-1

TITLE: RECOMMENDATION OF STRUCTURAL JOINTS FOR ASSEMBLY

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ISSUING ORGANIZATION: DEVELOPMENT DESIGN, 2-6166

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APPROVED BY J. D. Conannon

APPROVED BY _____

DEC 89 1966

SHEET 1

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ABSTRACT

This report is a Class II Research document which contains information to assist the preliminary and conceptual design engineer in selecting a variety of missile jointing methods:

Pin and Sleeve Joints, Lap and Overlap Joints

Welded Joints, Riveted Joints, Bolted Joints

Raceway Joints

In addition, the report includes a bibliography of the literature available on the subject of missile jointing. The report is intended for use by the preliminary and conceptual design engineer in the selection of a jointing method for a missile.

SYNOPSIS

1. Purpose

2. Scope

3. Method

4. Results

5. Conclusions

6. References

7. Notes

8. Bibliography

9. Pin and Sleeve Joints

10. Lap and Overlap Joints

11. Welded Joints

12. Riveted Joints

13. Bolted Joints

14. Raceway Joints

15. Summary

REFERENCES

1. Anderson

2. Baker

3. Thompson

4. George

5. F. Martin

6. L. Jones

7. V. Gambrell

8. C. Harbaugh

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USE FOR TYPE-CERTIFICATION MATERIAL ONLY

1.0

INTRODUCTION

This document was prepared to compile a source of design information useful to the preliminary or conceptual design engineer. The intent is not to present methods with which an engineer can design structural interface joints on missiles, but to assemble in one document, a cross-section of state-of-the-art designs.

It is recognized that a design engineer can arrive at a feasible design of a missile joint with no assistance. However, this takes a certain amount of time depending on the type of joint and its use. The engineer must investigate the loads, environment, cost, etc., or else he must initiate a literature search to see what similar joint has been used successfully in the past. With this document a designer will be able to select a feasible, proven joint design using only gross loads and environment data. This is usually sufficient for preliminary or conceptual design work since loads and environmental data are usually estimates at this stage. In addition, if the joint selected is one with which Boeing has had previous experience, the cost estimator can more accurately cost the proposed design concept.

The format of the document has been prepared to facilitate these tasks as much as possible. For each joint a sketch is given with dimensions if known. The loads to which the joint is designed and the environment to which the joint will be subjected are also summarized to the extent that such data is available. A short written description and project use is provided to give information on what type of use the joint might be applicable. References are listed, if available. Finally, titles of paragraphs which contain descriptions of specific joints are underlined for the convenience of the reader.

2.0 PAYLOAD STAGE JOINTS

This section covers the variety of structural joints designed to (1) attach the payload to the booster, (2) separate the payload from its booster, (3) attach the payload's ascent cover to the payload or booster and (4) separate the ascent cover in flight.

Figure 2-1 schematically shows the typical location of the four types of joints on a payload stage. It should be referred to as a guide to a specific type of joint. It is not intended that a given application require all of the indicated joints or that they be located as shown. For example, certain ascent covers have "over-the-top" removal and hence have no longitudinal separation joint. Or, separation and assembly joints may be integrated into one structural joint. For clarity, all joints are shown here as separate items for reference on Figure 2-1.

2.1 ASSEMBLY JOINTS

These joints serve to provide field attachment of the payload to the booster or the ascent cover to the booster. The joint may or may not be integral with the separation joint. If it is, a cross reference to that particular joint in Section 2.2 is made.

2.1.1 PAYLOAD ASSEMBLY JOINTS

These joints are shown on Figure 2-1 to be located on a "payload adapter", depicted as a frustrum of a cone. This is typical of satellite payloads on space boosters and is generally applicable to cases where the payload has a different diameter than the booster. Where diameters are nominally the same, the payload may be attached directly to the booster and this joint may be quite similar in appearance to booster interstage joints. Both types are shown in this report.

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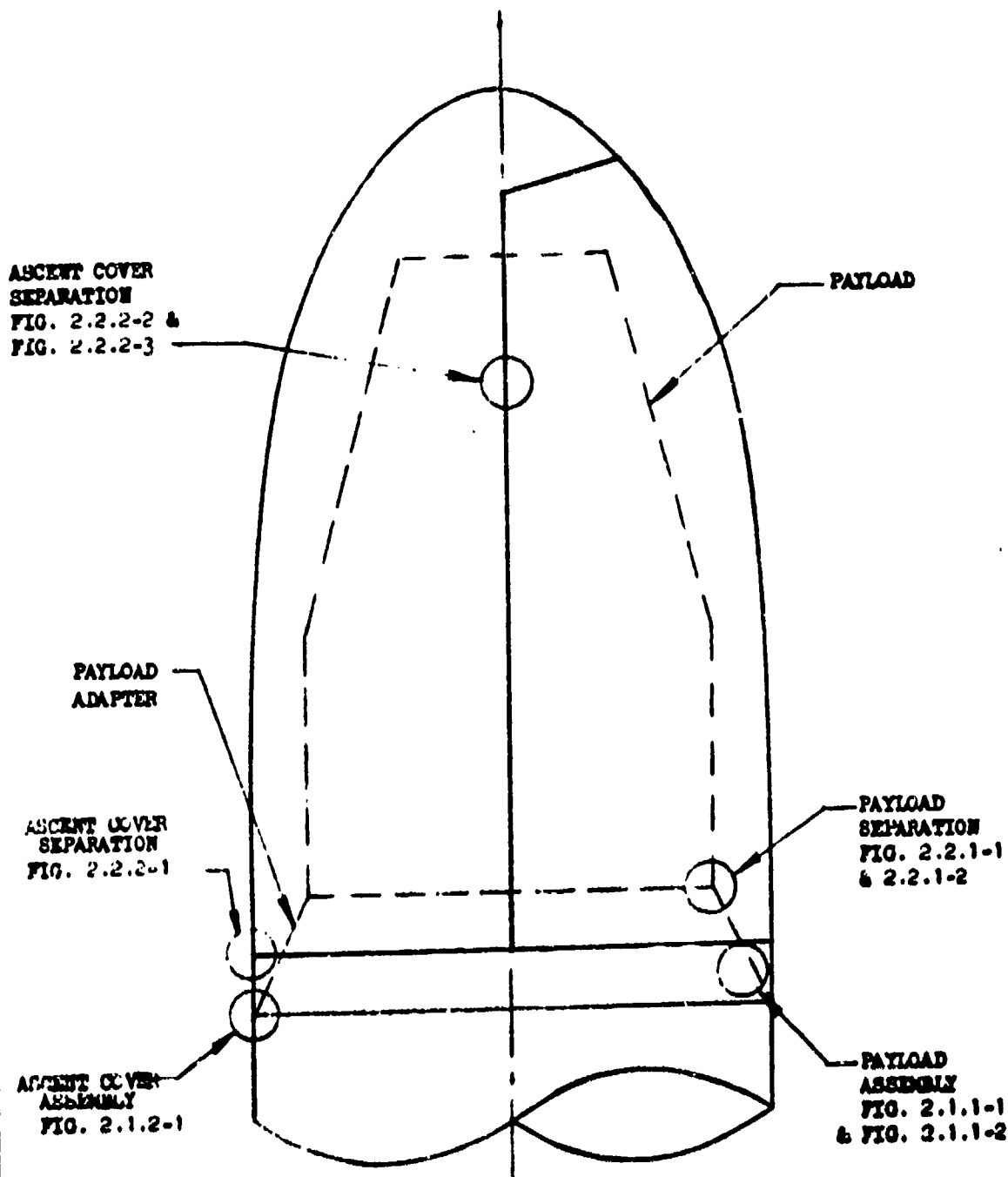


Figure 2-1: PAYLOAD STAGE JOINT INDEX

2.1.1 (Cont'd)

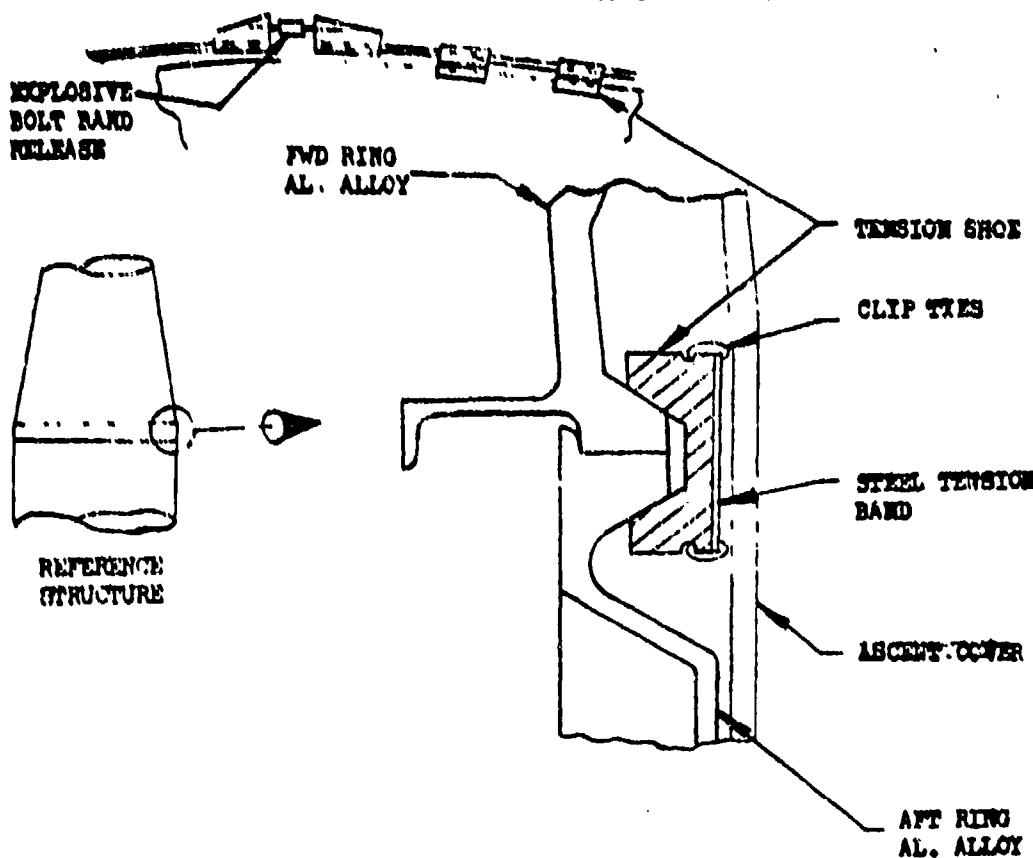
Frequently the post boost vehicle includes multiple instrumentation packages or warers (Reference Figure 2-2). These may be assembled essentially by repeating the basic lap joint structure as required by the number of packages to be assembled (Reference Figure 2.1.1-2).

2.1.1.1 COMBINED ASSEMBLY & SEPARATION JOINT (FIG. 2.1.1-1)

The joint shown schematically on Figure 2.1.1-1 serves the dual purpose of assembly and separation. A tension band is fitted over the interface of the butted flanges of the sections to be joined. The band is drawn tight by a turnbuckle arrangement which is also an explosive device. When actuated, the explosive device releases the band, permitting the sections to separate. Similar devices were used on Minuteman and at the separation plane of the Burner II payload. Examples in more detail are shown on Figures 3.3-5 through 3.3-9.

US' FOR TYPE-RTTCN WA TRIAL ONLY

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COMBINED ASSY & SEPARATION JOINT

DESIGN LOAD TO BE ADDED

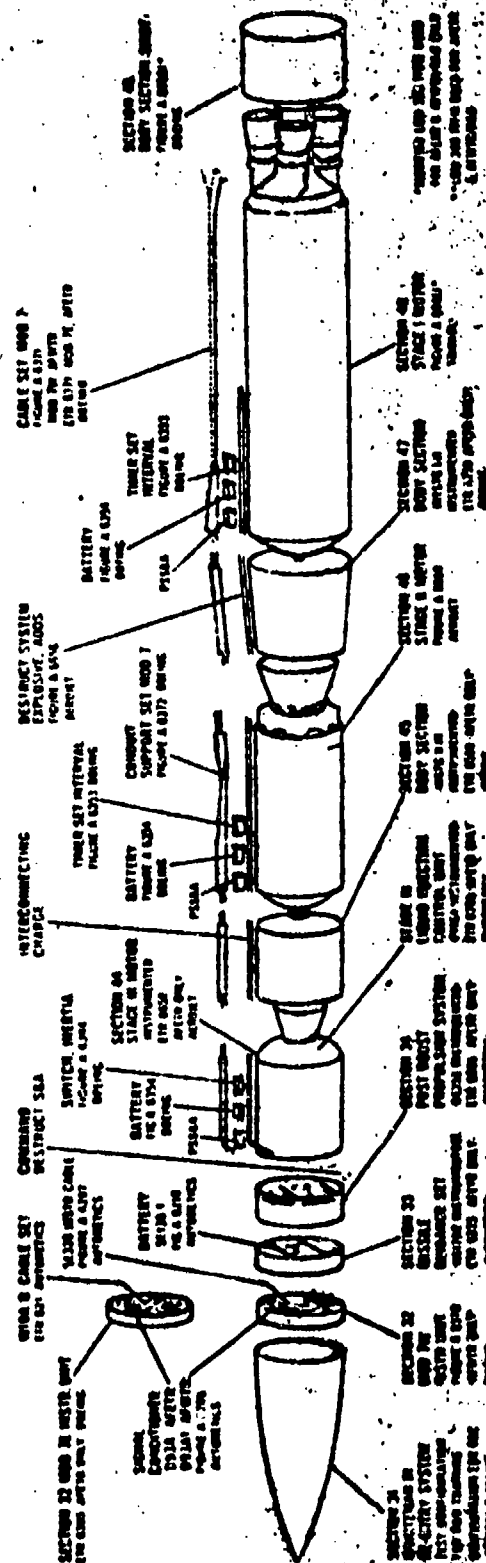
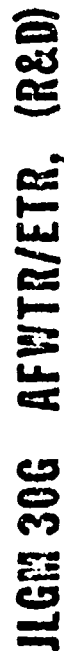
MATERIAL - ALUMINUM

FIGURE 2.1.1-1

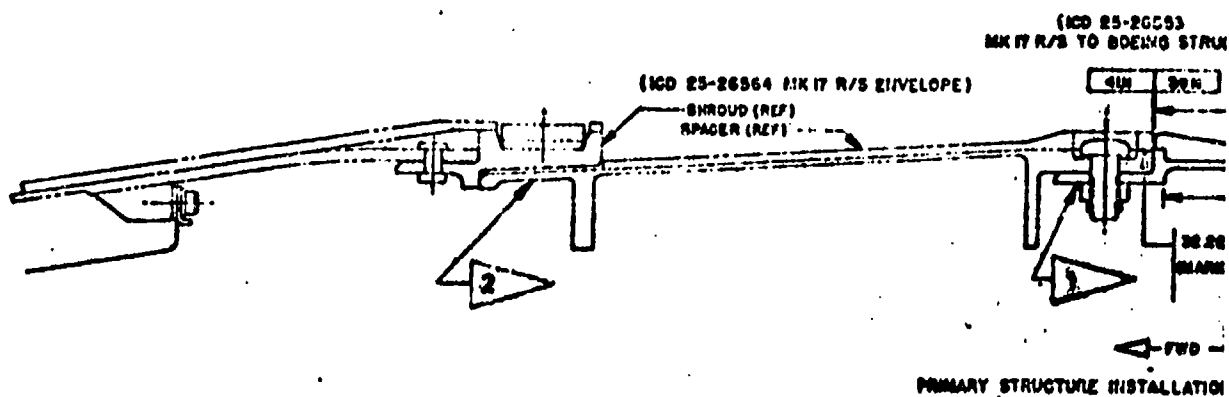
REFERENCE: MINUTEMAN ENGINEERING ICD 25-37645
ICD 25-37647

SEE EXAMPLES IN SECTION 3.3

02-125944-1
REV A

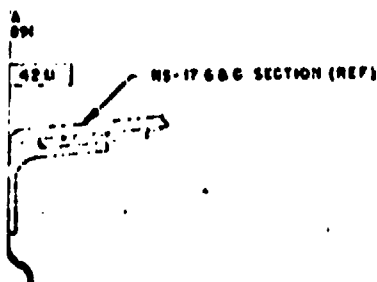
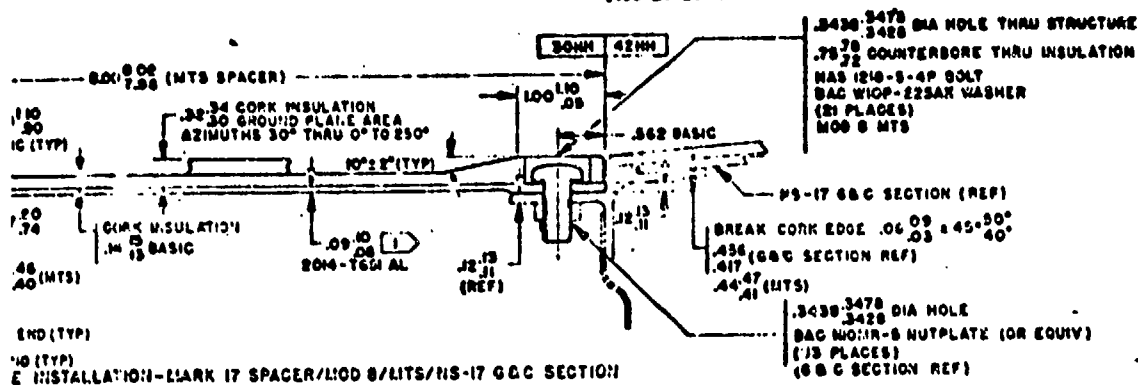


SHT.



PRIMARY STRUCTURE INSTALLATION

(MSG 25-28307 CTLI/MOD 8/MTS TO SAC SECTION)



ALTHOUGH SOMEWHAT DIFFERENT IN
DETAIL, THIS CONFIGURATION SHOWS
THE BASIC & AP JOINT COMMON TO THE
INSTRUMENTATION ASSEMBLY

THIS JOINT SHOWN IN GREATER DETAIL
ON FIG. 2.1.2-1.

**(D) BASIC DIMENSION SHOWN.
SKIN GAGE IN AREAS
OF CUTOUTS IS HEAVIER**

**PRIMARY STRUCTURE - INSTALLATION
MOD 8/MTS INSTRUMENTATION SPACERS
MOD 8-LO-10**

FIGURE 2.1.1-2

SHEET 12

2.1.2 ASCENT COVER ASSEMBLY JOINTS

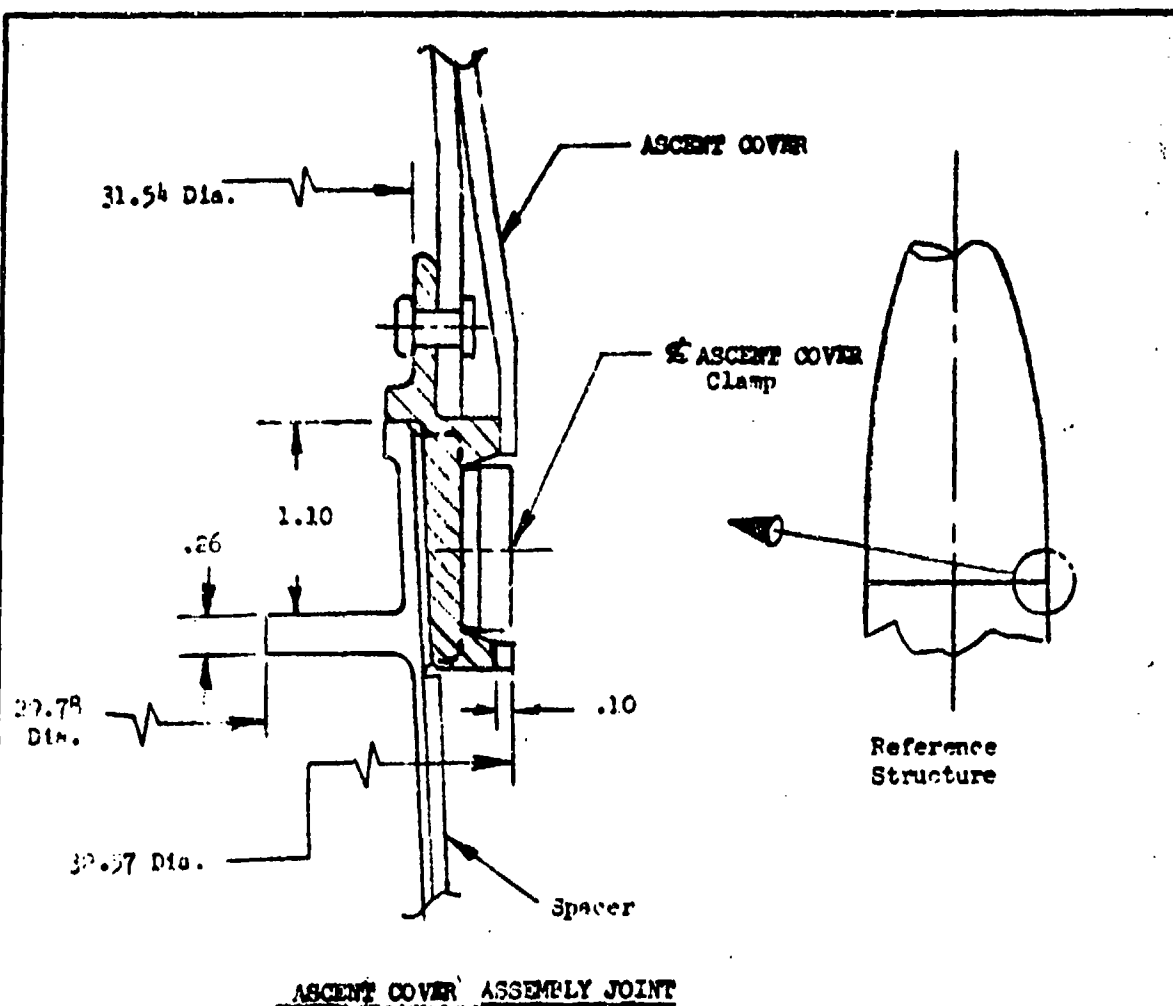
Figure 2-1 locates these joints at the intersection of the booster and payload adapter. Another common location is direct attachment to the payload itself. Others will become apparent as the engineer encounters different applications. The conditions of interest are how much of the payload need be exposed or covered at different phases of the mission, how much protection can be acquired by dual purpose structure (Integrating the ascent cover as part of the payloads primary structure), and the desire to discard as much weight as early in the mission as possible.

2.1.2.1 ASCENT COVER ASSEMBLY JOINT (FIG. 2.1.2-1)

Assembly of an instrumentation package to the Ascent Cover is accomplished by this joint in a concept study considered for Minuteman III. It uses overlapping rings which are held by the Ascent Cover Clamp strapped in tension around the outside of the assembly. The assembly surface under the clamp is composed alternately of portions of the inside and then the outside ring in a tongue and groove arrangement. Tangs on the outer ring slide into matching grooves on the inner ring to present a continuous external surface. Consequently the Ascent Cover Clamp bears equally on both rings. An ordnance device coupled to a system of cams is fired to release the tension and permit section separation.

USE FOR TYPE B-11 EN MATERIAL ONLY

USE FOR DRAWING AND HANDWRITING - NO TYPEWRITTEN MATERIAL



Scale None

DESIGN LOAD - Not Available

AVERAGE DIAMETER - As Shown

MATERIAL - 2014-T6 Al.

FIGURE 2.1.2-1

REFERENCES: Minuteman III Engineering DWG. ICD 25-26564

2.2 SEPARATION JOINTS

The separation joints described in this section provide in-flight release of the payload or the ascent cover from the missile. The joints may be part of integral joints combining the function of assembly and release, in which case a cross reference to ASSEMBLY JOINTS, Section 2.1 will normally be made.

2.2.1 PAYLOAD SEPARATION JOINTS

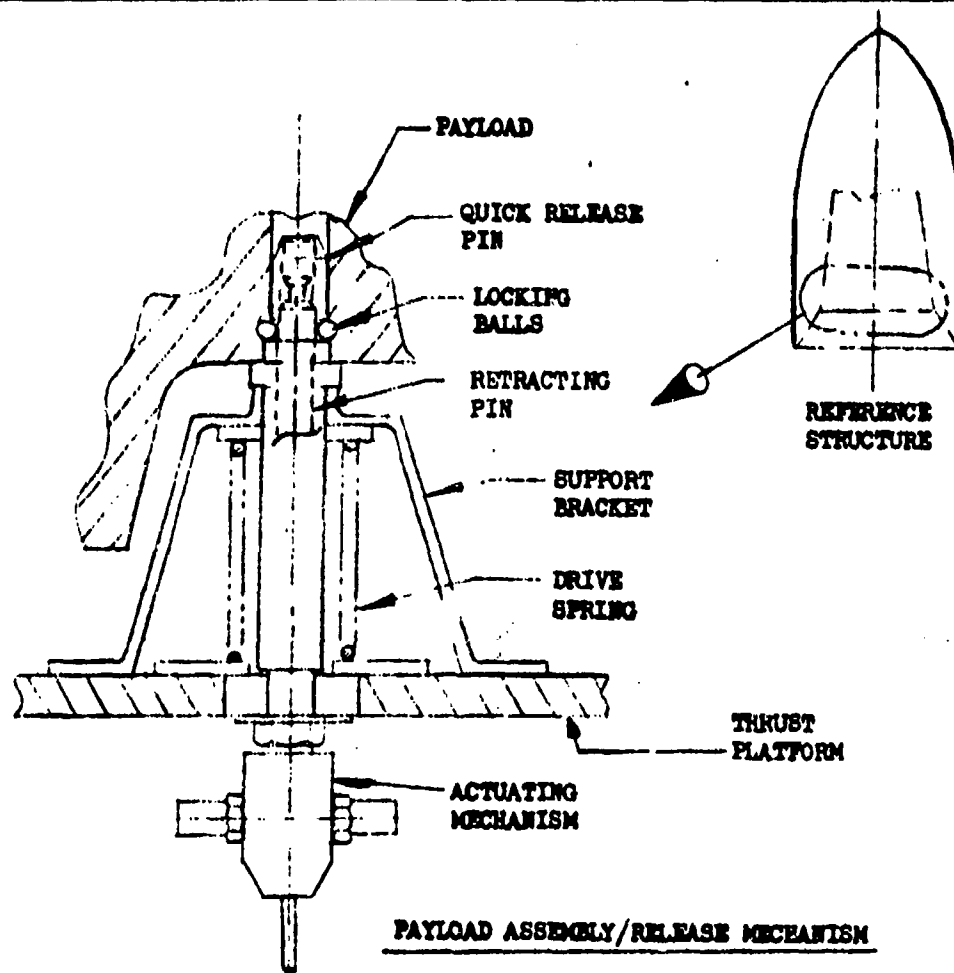
These joints are commonly located as shown in Figure 2-1 or at the booster interface. The latter type is not shown here. In some cases, additional mechanisms (springs, ordnance thrusters, etc.) are used for separation impulse. These will not be discussed in this document and mention will be made only when necessary to show clearance or functional association with the joint.

2.2.1.1 PALL LOCK RELEASE MECHANISM (FIG. 2.2.1-1)

This joint incorporates a commercially available ball lock into a device to retain and release a payload. Energy is supplied by springs and ordnance device. The actuating mechanism retracts the pin freeing the payload.

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SCALE: NONE

DESIGN LOAD



FIGURE 2.2.1-1

REFERENCE: MINUTEMAN TECHNOLOGY
D2-36136-1, MULTIPLE R/V SPIN THRUST MECHANISMS
O.E. DOCUMENT 655D7020

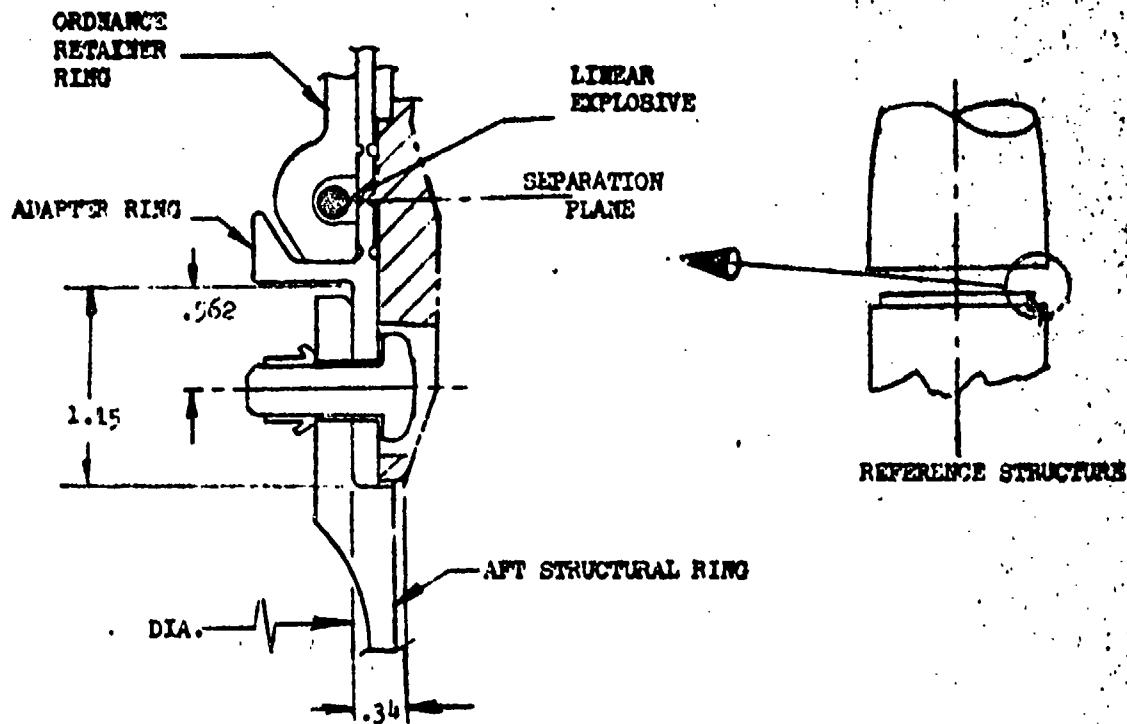
1 BSD EXHIBIT 62-123

2.2.1.2 PAYLOAD SEPARATION JOINT (FIGURE 2.2.1-2)

This joint assembles the post boost propulsion system (PBPS) and the third stage motor. Upon actuation of the linear explosive, complete severance of the longitudinal tension capability is provided while retaining shear and compressive capabilities by the butt-lap joint between the ordnance retainer ring and the adapter ring flange until physical separation of the post boost vehicle (PBV) and the Stage 3 motor...

Adaptations of this joint provide stage to stage separation capability on Minuteman III (Reference Figure 2-3).

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STAGE 3. TO PBPS SEPARATION JOINT, M² III



CORK

SCALE NONE

DESIGN LOAD - SEE REFERENCE
AVERAGE DIAMETER - 52.0 O. D.
CROSS SECTIONAL AREA - TO BE ADDED
MATERIAL - 2014 T6 AL

FIGURE 2.2.1-2

REFERENCE: MINUTEMAN III ENGINEERING
D2-30044-3A1, FIG. A 6553

DWG ICD 25-60024

- 1 SEE TABLE FOR DESCRIPTION OF INTERFACE FASTENERS
- 2 MATL: ALLOY STEEL, N.T., 160,000 TO 200,000 PSI PER MIL-H-4875 FINISH: SUPPLIED CADMIUM NICKEL PLATE PER AMS 2416
- 3 MATL: ALUM. ALLOY, 2024-T3 OR T4, QQ-A-362
- 4 MATL: SAE 1040, 1050, 1060, N.T., ROCKWELL C38-44 FINISH: CADMIUM PLATE PER QQ-P-416, TYPE II, CLASS 3
- 5 MATL: ALLOY STEEL, N.T., 160,000 TO 200,000 PSI ULTIMATE TENSILE STRENGTH PER MIL-H-4875, ROCKWELL HARDNESS C40-45, FINISH: CADMIUM PLATE PER QQ-P-416, TYPE II, CLASS 3
- 6 MATL: 2024-T3 OR T4 CLAD ALUMINUM, QQ-A-280/3 FINISH: BAC 3011, TYPE I
- 7 LOCKBOLT, DESCRIPTION TO BE DETERMINED (AUTONEUTICS SUPPLIED)
- 8 MATL: 303 SE CRCS PER QQ-S-743 N.T., NONE, FINISH: CADMIUM PLATE PER QQ-P-416, TYPE II, CLASS 3
- 9 MATL: CARBON STEEL, HEAT TREATED, FINISH: SUPPLIED CADMIUM NICKEL PER AMS 2416
- 10 AUTONEUTICS TO DETERMINE REQUIREMENTS, NTS QUANTITY BASED ON BOLTING CALCULATIONS ONLY.
- 11 EXCEPTION: HAS 1384-26 (1 PLACES, SAGWAY AREA). SEE HAS SPEC. FOR MATL, N.T. & FINISH
- 12 EXCEPTION: HAS 1386-412 (1 PLACES, SAGWAY AREA). SEE HAS SPEC. FOR MATL, N.T. & FINISH

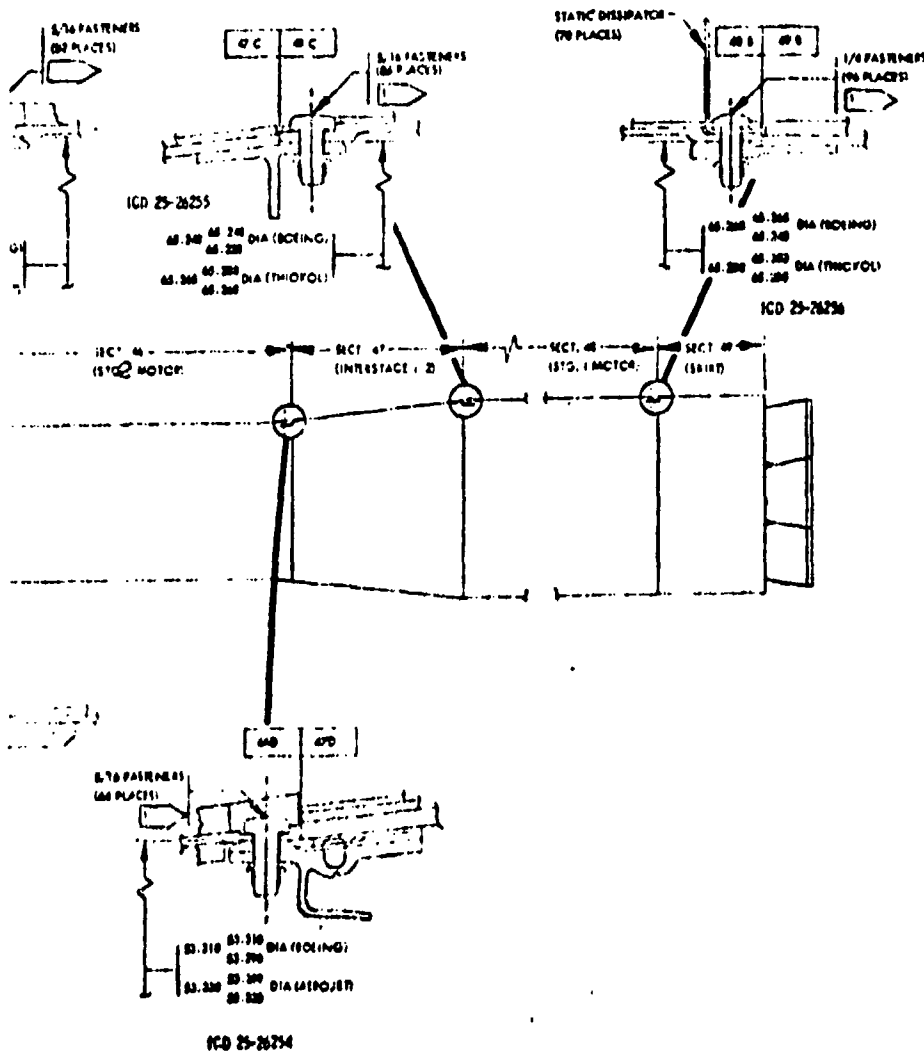


FIGURE 2 - 3: SUMMARY MAJOR SECTION ASSEMBLY JOINTS
LGM 30G MINUTEMAN III

2.2.2 ASCENT COVER SEPARATION JOINTS

Two types of joints are indicated in Figure 2-1, the circumferential and the longitudinal joint. The longitudinal joint is not always used, depending on the mode of ascent cover deployment. Both types of device are shown in this section. Comments of paragraph 2.2.1, PAYLOAD SEPARATION JOINTS, also apply here.

2.2.2.1 NOSE CONE SEPARATION JOINT (FIG. 2.2.2-1)

This detail is of a joint used to separate the nose cone of the HIREX missile and thereby provide a high drag blunt nose exposure to the air stream.

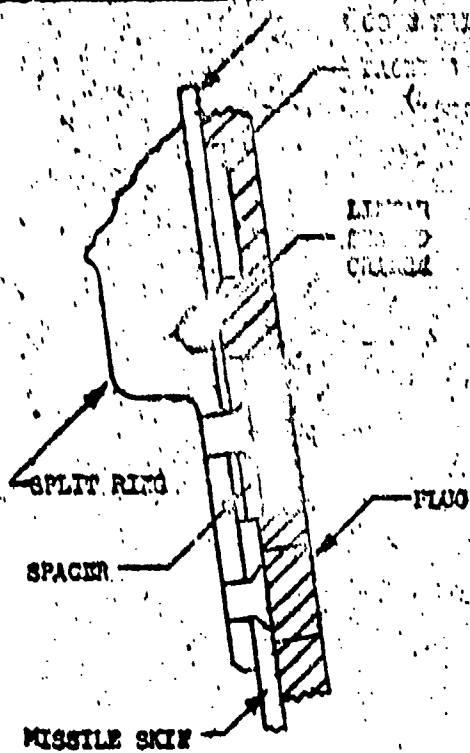
The joint is an uncomplicated design similar in many respects to a fabrication joint - two skins are butted together and bolted using bolts and nut plates. The separation is done with a linear shaped charge which expends its energy primarily in one direction, in this case outward, to cut the nose cone skin. This impulse is sufficient to make the physical break but not to effect total separation. To do this, a gas generator and thruster is used to "blow" the two pieces apart.

For additional details of the ordnance used, refer to section 5.1.

2.2.2.2 LONGITUDINAL COVER SEPARATION JOINT (FIG. 2.2.2-2)

This joint is a design concept developed as part of an ascent cover study using Burner II design load requirements. The joint provides longitudinal separation of the cover followed by separation and blow off along the hinge line.

DRAWING AND MANUFACTURING - NO INTERMEDIATE MATERIAL



SECTION A - A



CORK



RUBBER

NOSE CONE SEPARATION JOINT

DESIGN LOAD - -

AVERAGE DIAMETER - SEE REF. BELOW

CROSS SECT. AREA - N.A.

MATERIAL - ALUMINUM

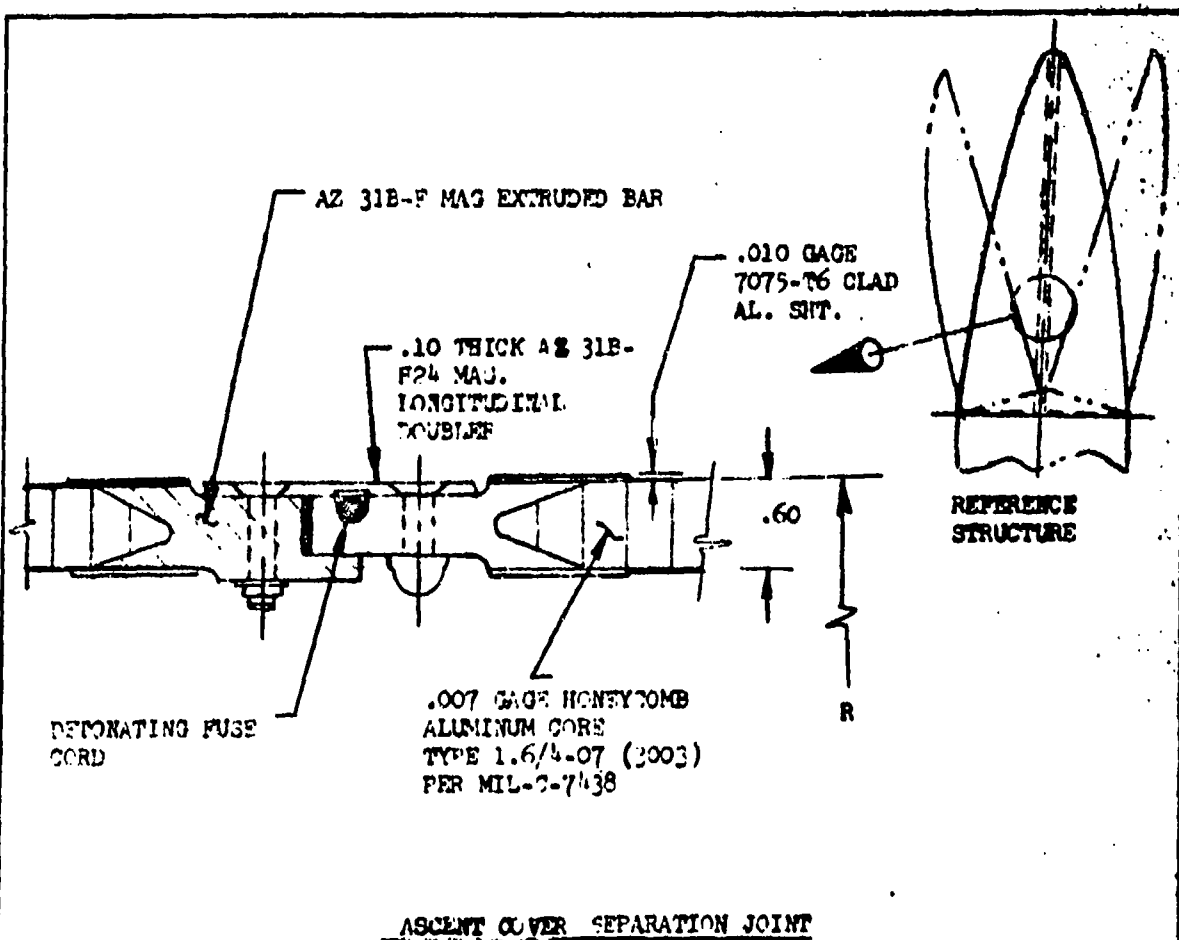


TO BE ADDED

FIGURE 2.2.2-1

REFERENCES: HILBEX PROGRAM DWG: 25-39910

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SCALE NONE

DESIGN LOAD TO P.V. APPLIED


AVERAGE DIAMETER - N. A.

MATERIAL - AS SHOWN

FIGURE 2.2.2-2

REFERENCES: D2-23808-1, ASCENT SHROUD DESIGN, FIGURE 1, p 7

2.2.2.2 MECHANICAL HEAT SHIELD JOINT (FIG. 2.2.2-3)


To prevent possible payload contamination, a linear shaped charge system for separation of the heat shield halves of Burner II was ruled out in favor of a mechanical separation system. This mechanical system basically consists of six pins along each separation line that join the honeycomb structured heat shield halves and are pulled by two pyrotechnic thrusters for separation. A Pin Release Strap connects the six pins on each separation line so that they respond simultaneously to thruster actuation. 

The essential joint component of this system is illustrated schematically in the two views of Figure 2.2.2-3. The joint combines three elements to provide structural continuity between heat shield halves as follows:

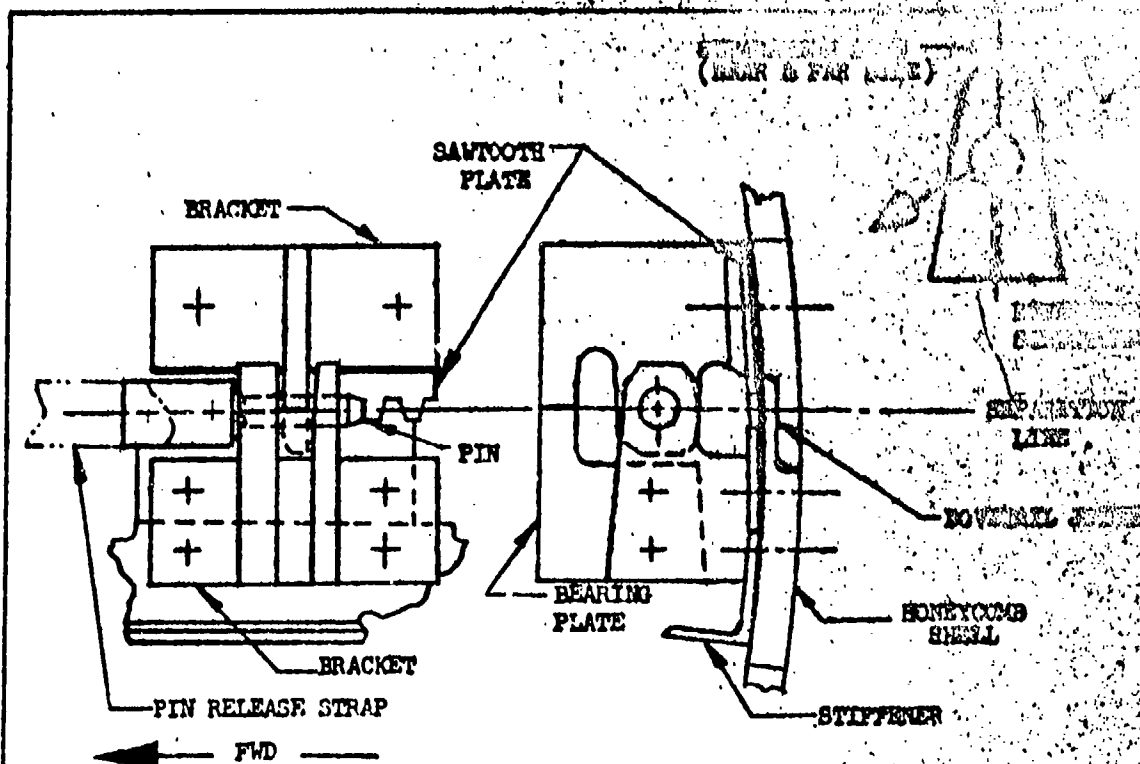
- a. The Pinned Joints designed to provide ring bending shear and normal force continuity.
- b. A Dove-Tail joint along the edges of the two halves that provide ring bending continuity between the pinned joints.
- c. Mating sawtooth plates at each pinned joint that provide beam shear continuity between the two heat shield halves.

The critical design considerations for these joint elements are dictated by airloads.

The attached stiffener angle along the separation line reduces deflections during thruster operation.

 Ordnance Engineering Associates, Inc. Report No. OAE P/N 2066100-1,
Rev. J "Acceptance Test Report for Pilot's Hatch Thruster, dated
Sept. 26, 1966.

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MECHANICAL SEPARATION JOINT, HEAT SHIELD

SCALE : None

DESIGN LOAD: ± 80 in-lbs/in Limit
 ± 100 in-lbs/in Ultimate

DIAMETER: 47 in (approximately) at Station Shown

MATERIAL: See Reference Below

FIGURE 2.2.2-3

REFERENCES: Burner II Dwg. 25-53735
 Document D2-113381-1

3.0 ROOSTER STAGE JOINTS

This section includes the variety of structural joints designed to (1) enable the assembly and disassembly of missile segments for purposes of manufacture, transportation and maintenance in the field and (2) enable the staging separation necessary for the missile's mission flight profile.

Figure 3-1 schematically shows the typical location of the joints on a missile booster segment and interstage. This is representative of any stage. It is not intended that a given application require all of the indicated joints or that they be located as shown. As an example, an inflight separation function and a field joint may be integrated into a single structural joint. For clarity, all joints are indicated as separate items on Figure 3-1.

3.1 ASSEMBLY JOINTS

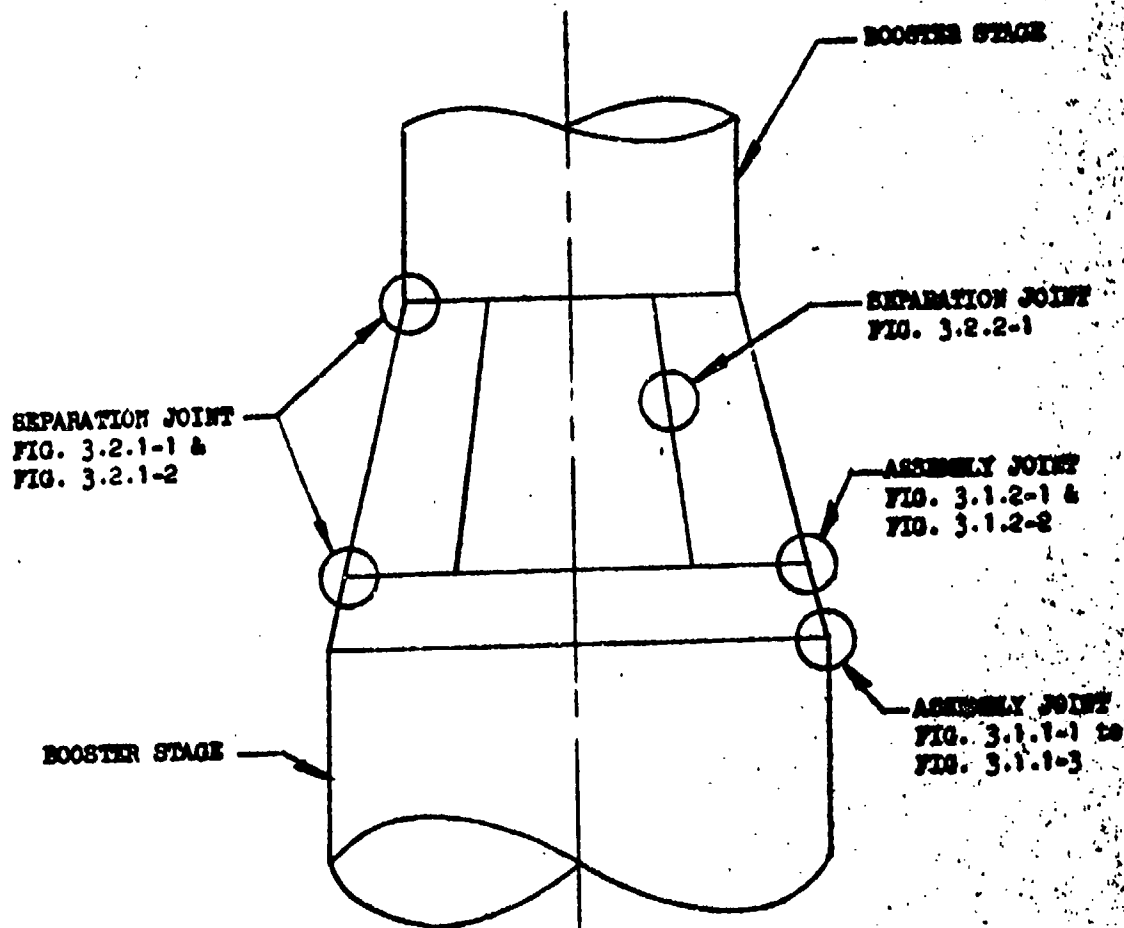
The assembly joints described in this section are those used to connect segments of the booster to each other, through interstages or not. This connection might be purely a shop fabrication assembly or it might be a field operation done many times. The joints may be integral joints as in payload stages. If so, cross referencing is done.

3.1.1 INTERSTAGE OR ROOSTER ADAPTERS

This section covers the assembly joints made between one booster stage and another, usually through an interstage. The joints are usually referred to as "adapter rings" and commonly form the interface between two manufacturers (Reference Fig. 2-3). These rings may be purely assembly or may be integrated with a separation joint if the location is one where staging is desirable. Both types are covered here.

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USE FOR DRAWING AND HANDWRITING — NO TYPEWRITTEN MATERIAL



BOOSTER STAGE JOINT INDEX

FIGURE 3-1

3.1.1.1 INTERSTAGE ADAPTER ASSEMBLY JOINT (FIG. 3.1.1-1)

This joint detail is a section through a circumferential joint used on the Minuteman missile. The dimensions given are typical of the Stage 1 - Stage 2 interstage as are the diameter and cross sectional area. The ring's characteristic shape is also typical of the Stage 2 - Stage 3 interstage on Minuteman. For reference, the numbers in parenthesis pertain to that ring.

The ring is a dual purpose joint. It permits both field assembly and fabrication assembly in the shop. It also functions as an inflight separation joint (Ref. Section 3.2.1.1).

Two bolt circles are provided in the joint, both to be used with bolt-nut plate combinations. The lower bolts are primarily fabrication fasteners and are backed with standard nutplates. The upper bolts are for field assembly and disassembly and are backed with floating nutplates. Cork plugs are commonly used to replace insulation removed during disassembly.

Structurally, the main ordnance carrying ring is not the primary load carrying member. Compression loads are reacted by a butting together of the interstage skins, tension loads by the tension tie. The joint is designed to react all boost flight loads as well as silo overpressure.

3.1.1.2 INTERSTAGE ADAPTER ASSEMBLY JOINT (FIG. 3.1.1-2)

This joint is designed for assembly of an interstage (or other structure such as a test module) on top of a booster stage. The assembly operation may be done in the manufacturing facility or the field. The ring is typical of that used on the Minuteman (F-Missile) program to join the Autonetics Guidance and Control module to the third booster stage.

USE FOR TYPEWRITTEN MATERIAL ONLY

3.1.1.2 (Cont'd)

The ring itself is riveted to the interstage structure and forms an integral component. The assembly operation is done then by means of the bolts and nutplates shown. Nuts may be used instead of nutplates, depending on the accessibility and "dropped-nut" considerations. Cork plugs are commonly used to replace any insulation removed during disassembly.

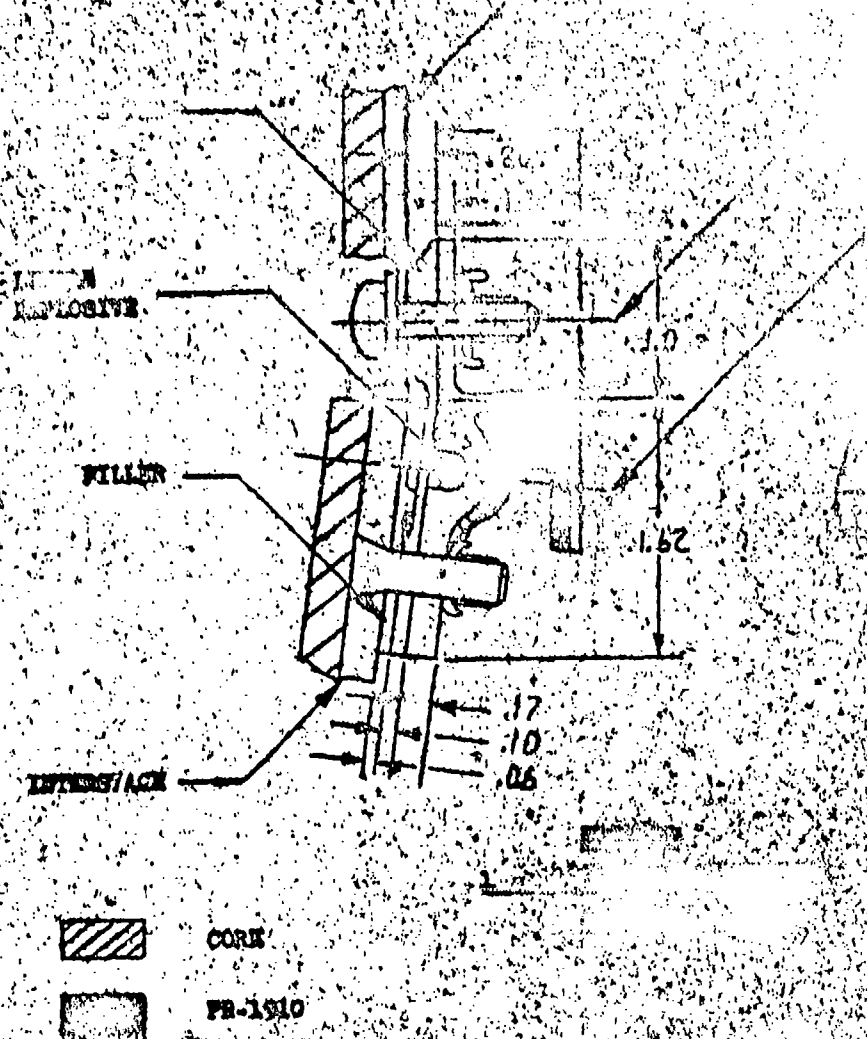
The joint is designed to retain its structural integrity throughout boost flight loads and silo overpressures.

3.1.1.3 STAGE TO STAGE ASSEMBLY JOINT (FIG. 3.1.1-3)

This detail is a section through a circumferential joint used on the HiBEX Missile. It is used to assemble the upper stage instrumentation package to the booster. The assembly operation could take place either in the fabrication facility or a munitions field facility.

The ring is riveted to the lower missile stage, which is made of fiberglass in this application. The upper stage is attached with bolt-nutplate combinations. The joint is designed to resist extremely high boost acceleration loads.

USE FOR TYPE 2-11EN MATERIAL ONLY



DESIGN LOAD - (CRITICAL) 913 #/IN TENSION LOAD

AVERAGE DIAMETER - 53.0 IN. OD (36.7 IN. OD),

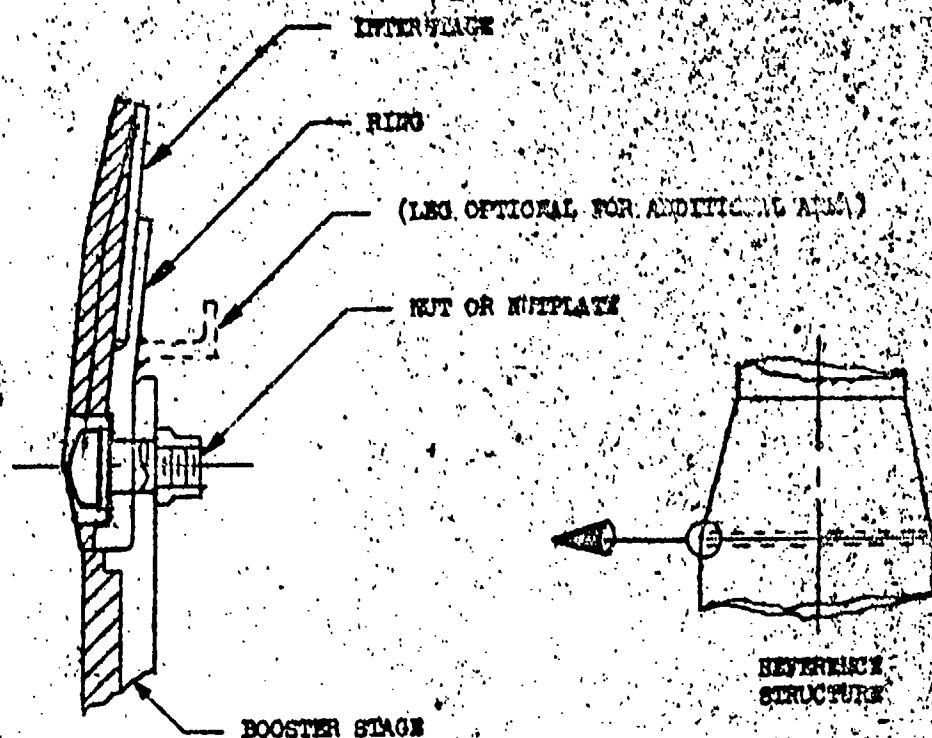
CROSS SECT. AREA - 1.003 SQ. IN. (1.156 SQ. IN.)

MATERIAL - 2024 AL.

FIGURE 3.1.1-1

REFERENCES: SEDWICKMAN ENGINEERING DWG 25-37645
25-37647

DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL



INTERSTAGE ADAPTER
ASSEMBLY JOINT

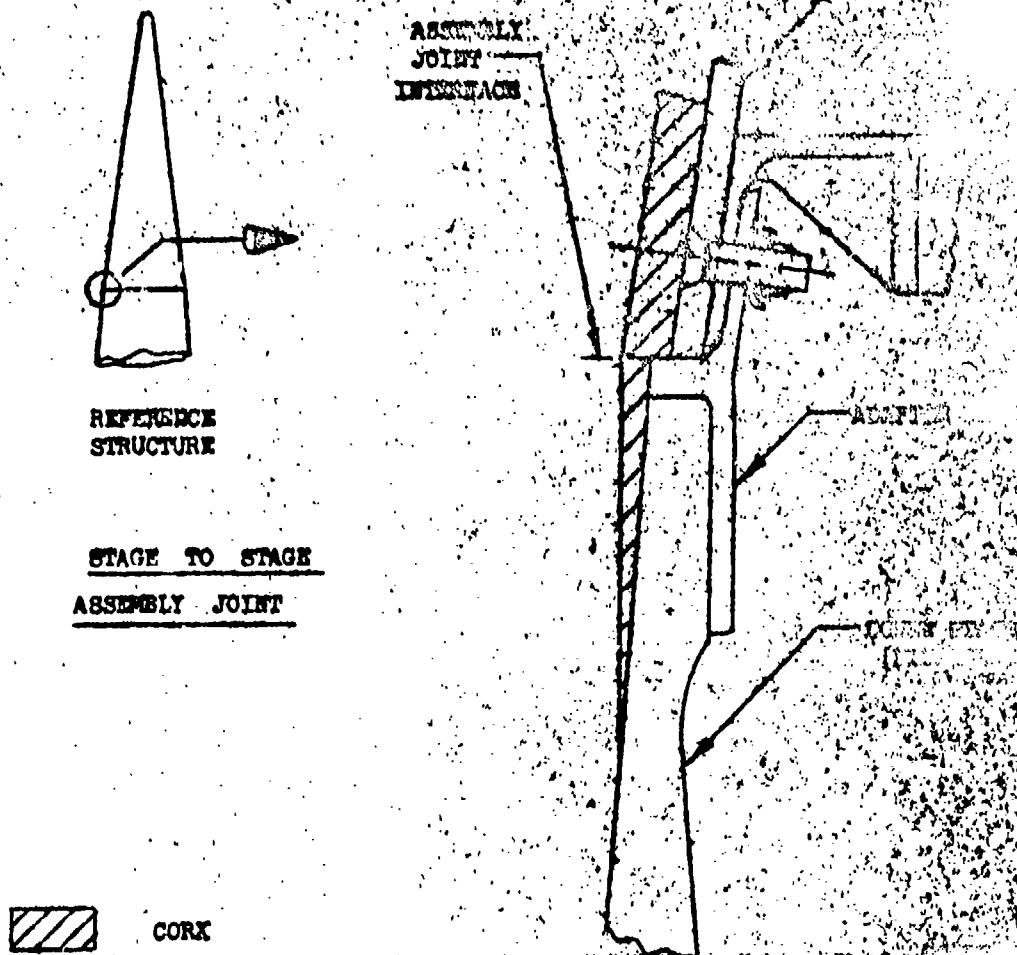


DESIGN LOAD - 387 $\frac{1}{2}$ IN. TENSION (RING BUCKLING CRITICAL)
AVERAGE DIAMETER - 65.2 IN. OD (APPROXIMATE),
CROSS SECT. AREA - UNKNOWN
MATERIAL - ALUMINUM

FIGURE 3.1.1-2

REFERENCES: MINUTEMAN INTERFACE CONTROL DRAWING 25-37645
25-37647

DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL



DESIGN LOAD - AXIAL LOAD = 201K lba. APPROXIMATE
BENDING LOAD = 80 psig
(EXTERNAL PRESSURE)
AVERAGE DIAMETER - 18 IN. OD,
CROSS SECT. AREA - TO BE ADDED
MATERIAL - ALUMINUM & FIBERGLASS

FIGURE 3.1.1-3

REFERENCES: HIREX PROGRAM DWG 25-39910

3.1.2 MIDBODY OR MID-INTERSTAGE RING JOINTS

These joints are almost entirely used in conjunction with a staging separation joint. Their purpose is to assemble the staged segments, usually in a fabrication environment.

3.1.2.1 INTERSTAGE ASSEMBLY JOINT (FIG. 3.1.2-1)

This joint detail is a section through a circumferential joint used on the Minuteman missile. The dimensions given are typical of the Stage 1 - Stage 2 interstage.

The ring is a dual purpose joint. It permits both field assembly and fabrication assembly in the shop. It also functions as an inflight staging joint (Ref. Section 3.2.1.2).

Two bolt circles are provided in the joint, designed for bolt-nut or bolt-nut plate combinations. The lower bolts are primarily fabrication fasteners and are backed with standard nuts. The upper bolts are also fabrication assembly fasteners but are backed with floating nutplates.

Structurally, the main ordnance carrying ring is not the primary load carrying member. Compression loads are reacted by a butting together of the interstage skins, tension loads by the tension tie. The joint is designed to react all boost flight loads as well as silo overpressures. A stiffener ring provides increased rigidity to resist bending loads at the joint interface.

3.1.2.2 INTERSTAGE ASSEMBLY JOINT (FIG. 3.1.2-2)

This joint detail is a section through a circumferential joint used on the Minuteman missile. The dimensions given are typical of the Stage 2 - Stage 3 interstage.

3.1.2.2 (Cont.)

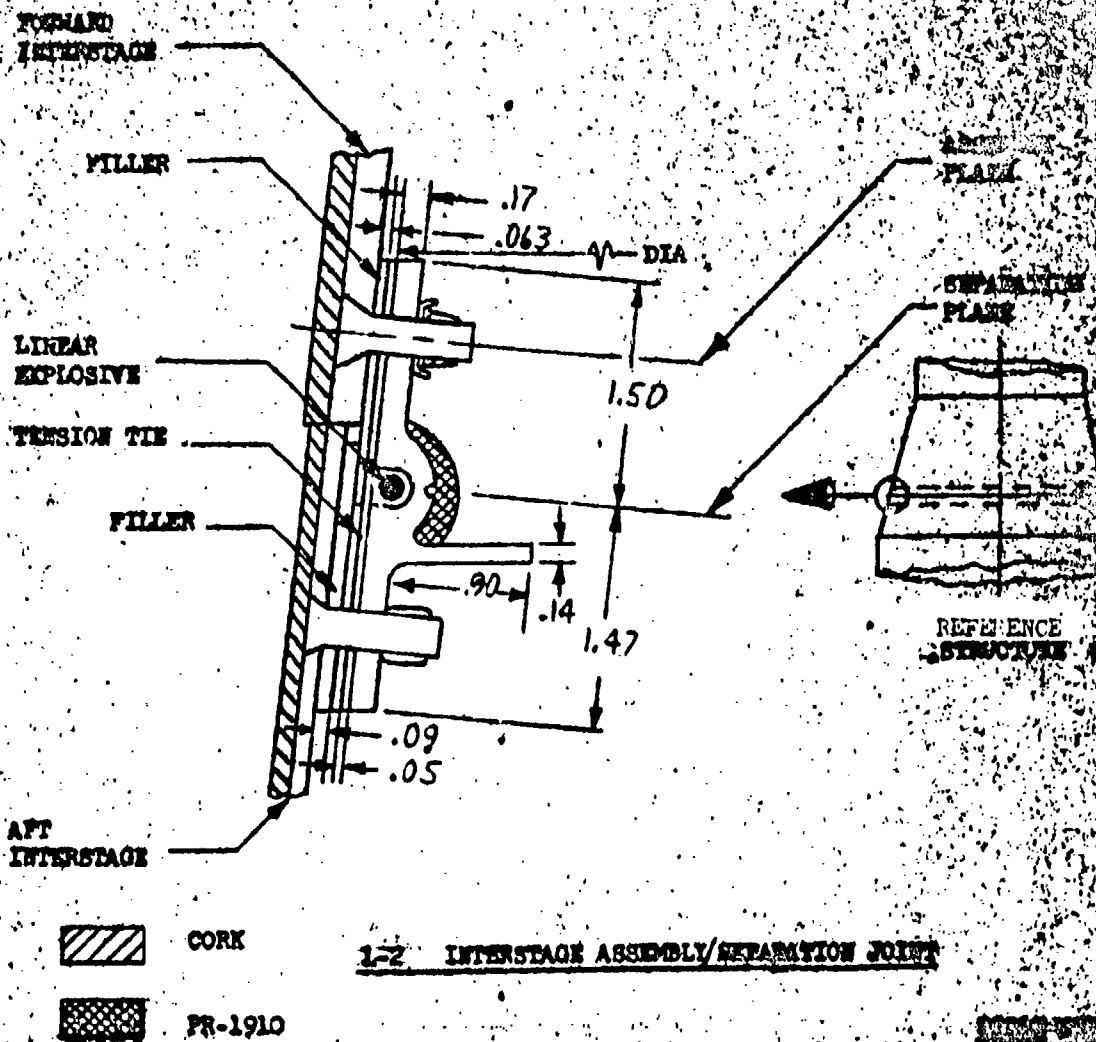
The ring is a dual purpose joint. It permits both field assembly and fabrication assembly in the shop. It also functions as an inflight staging joint (Ref. Section 3.2.1.2).

Two bolt circles are provided in the joint, employing different fastener combinations. The lower bolts are primarily fabrication fasteners and are backed with standard nuts. The upper bolts are also fabrication assembly fasteners but are backed with floating nutplates.

Structurally, the main ordnance carrying ring is not the primary load carrying member. Compression loads are reacted by a butting together of the interstage skins, tension loads by the tension tie. The joint is designed to react all boost flight loads as well as side overpressures.

USE FOR TYPEWRITING MATERIAL ONLY

DO NOT DRAW AND CONSIDERING - NO TYPE/ITEM MATERIAL

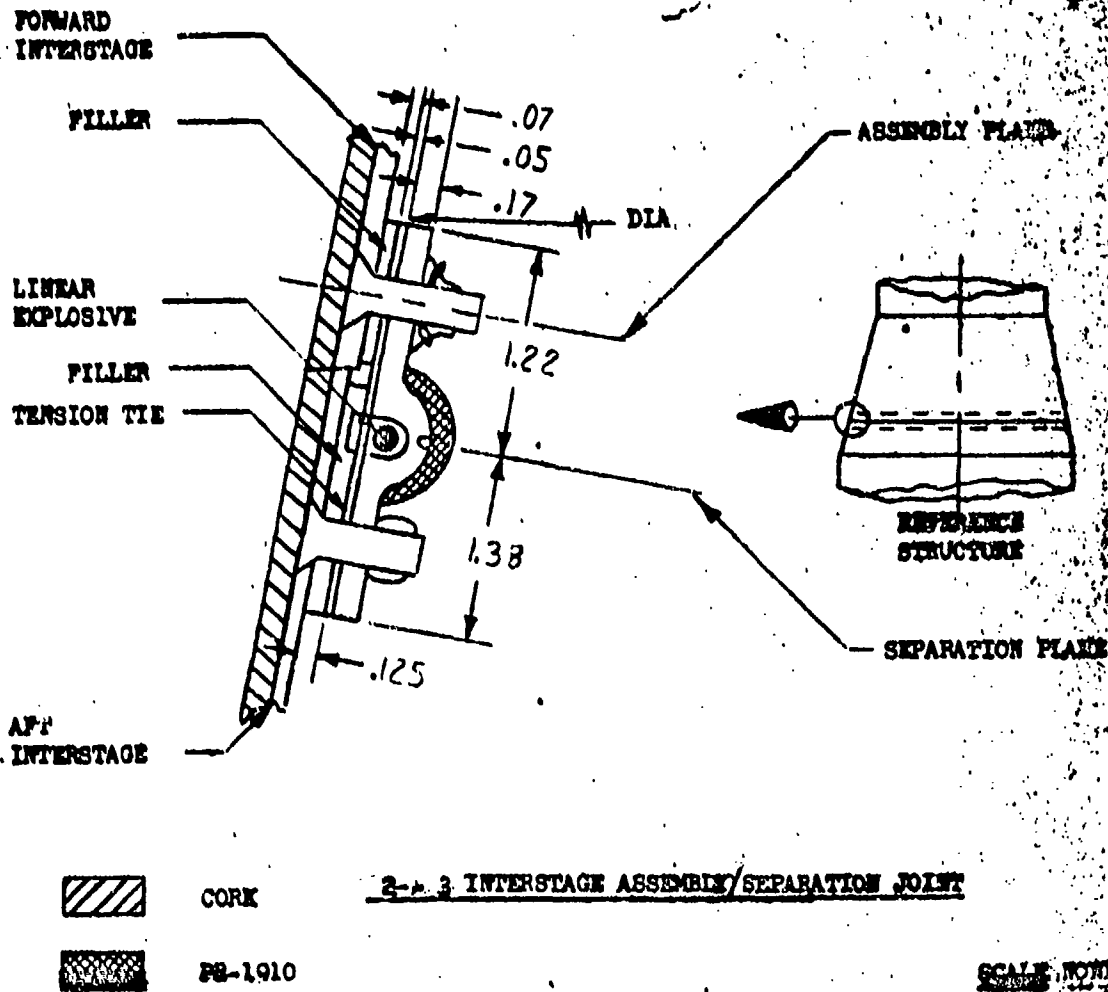


CRITICAL
DESIGN LOADS - 1200 #/IN TENSION, 1200 #/IN. BENDING
AVERAGE DIAMETER - 62.0 IN. OD,
CROSS SECT. AREA - 1.165 SQ. IN.
MATERIAL - 2024 AL.

FIGURE 3.1.2-1

REFERENCES: MINUTEMAN ENGINEERING DWG: 25-37645
25-37647

USE FOR DRAWING AND HANDLING - NO TYPEWRITTEN MATERIAL



DESIGN LOAD - 1000# / in. TENSION, SHEAR

AVERAGE IDIAMETER - 46.0 IN. OD,

CROSS SECT. AREA - .910 SQ. IN.

MATERIAL - 2024 AL.

FIGURE 3.1.2-2

REFERENCES: MINUTEMAN ENGINEERING DWG: 25-37645
25-37647

3.2 SEPARATION JOINTS

Described in this section are the variety of joints designed to provide inflight staging of a missile booster. This is the mechanism which separates a burned out motor from the remaining "live" booster stages. It also may separate an interstage structure from an associated motor case. As in most of the other joints described in this document, these joints may be part of integral joints combining other functions. When this is the case, cross referencing to appropriate sections will be made.

3.2.1 STAGING RINGS

These rings function to either "stage" an expended booster segment from an unexpended one or to separate an interstage from a booster. Figure 3-1 shows typical locations for this type of joint. In some instances they are used in conjunction with longitudinal joints to separate and segment an interstage. This is covered in more detail in Section 3.2.2.

3.2.1.1 INTERSTAGE ADAPTER BOOSTER SKIRT REMOVAL JOINT (FIG. 3.2.1-1)

This joint detail is a section through a circumferential joint used on the Minuteman missile. The dimensions given are typical of the Stage 2 - Stage 3 interstage as are the diameter and cross section area. The ring's characteristic shape is also quite typical of the Stage 1 - Stage 2 interstage on Minuteman.

The ring is a dual purpose joint. It provides the inflight interstage skirt removal function, working in conjunction with the longitudinal joint similar to that described in Section 3.2.2.1. It also functions as a field assembly joint (Ref. Section 3.1.1.1). The seal restricts transfer of hot gas into the Stage 3 motor area.

USE FOR TYPEWRITTEN MATERIAL ONLY

3.2.1.1 (Cont'd)

The separation impulse to provide the required function comes from a linear explosive charge. The ring is designed to contain any particle fragmentation from this charge. This function is enhanced by the use of a rubber-like material, PR-1910 (BMS 5-62) which can contain small fragments. The primary function of the material however is to absorb much of the shock of the explosion.

Structurally, the main ordnance carrying ring is not the primary load carrying member. Compression loads are reacted by a butting together of the stage skins, tension loads by the tension tie. The joint is designed to react all boost flight loads as well as silo overpressurer.

For additional details on the ordnance used in this joint, refer to Section 5.1.

3.2.1.2 BOOSTER STAGING JOINT (FIG. 3.1.2-1)

This joint detail is a section through a circumferential joint used on the Minuteman missile. The dimensions given are typical of the Stage 1 - Stage 2 interstage.

The joint has a dual purpose. It provides the inflight booster staging function, separating the upper stage from the expended stage. It also functions as an assembly joint (Ref. 3.1.2.1).

The separation impulse to provide the required function comes from a linear explosive charge. The ring is designed to contain any particle fragmentation from this charge by the use of a rubber-like material, PR-1910 (BMS 5-62) which can contain small fragments. The primary function of the material however is to absorb much of the shock of the explosion.

Structurally, the main ordnance carrying ring is not the primary load carrying member. Compression loads are reacted by a butting together of the stage skins, tension loads by the tension tie. The joint is designed to react all boost flight loads as well as silo overpressures.

For additional details on the ordnance used in this joint, refer to Section 5.1.

3.2.1.3 BOOSTER STAGING JOINT (FIG. 3.1.2-2)

This joint detail is a section through a circumferential joint used on the Minuteman missile. The dimensions given are typical of the Stage 2 - Stage 3 interstage.

The ring is a dual purpose joint. It provides the inflight booster staging function, separating the upper stage from the expended stage. It also functions as an assembly joint (Ref. 3.1.2.2).

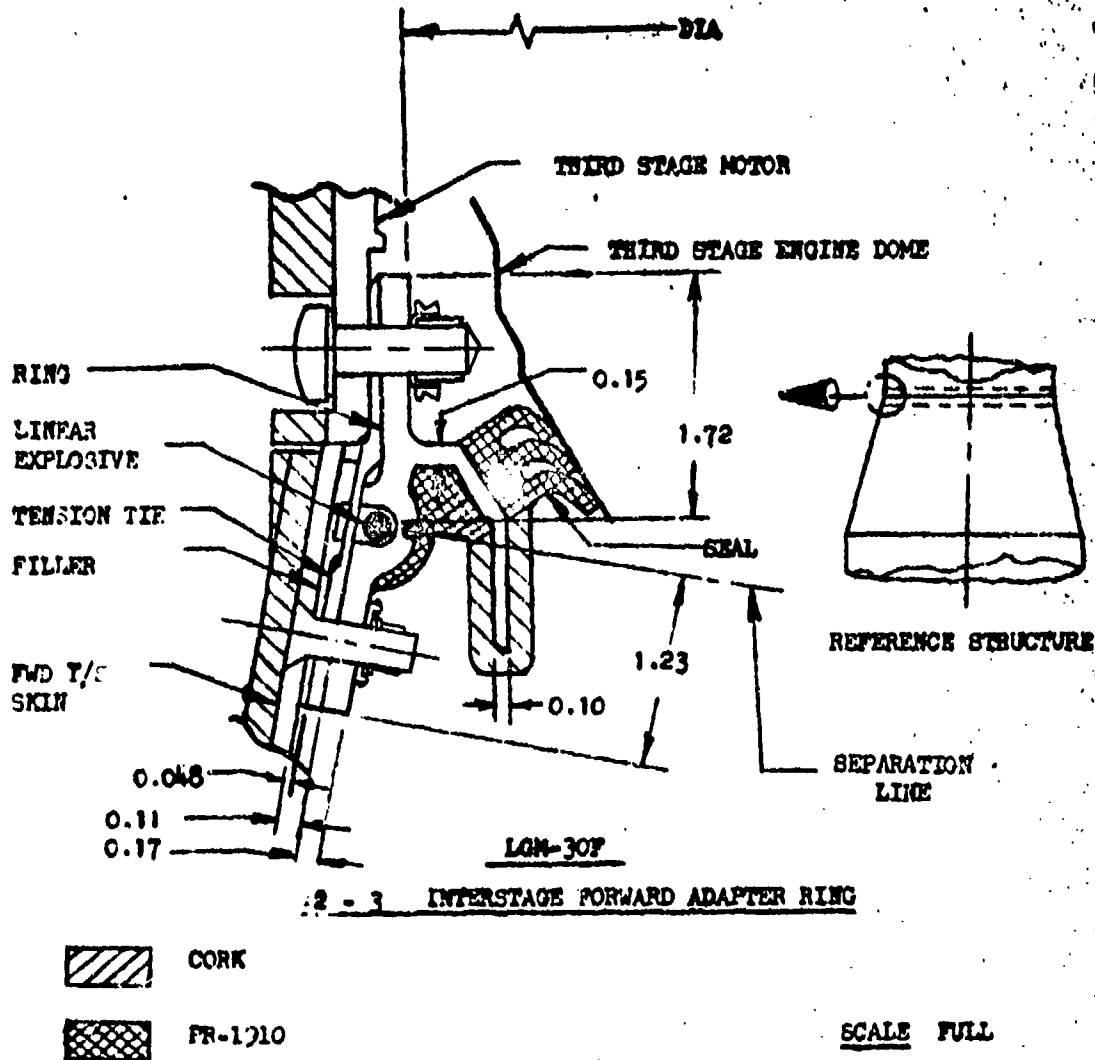
The separation impulse to provide the required function comes from a linear explosive charge. The ring is designed to contain any partial fragmentation from this charge by the use of a rubber-like material, PB-1910 (BMS 5-62) which can contain small fragments. The primary function of the material however is to absorb much of the shock of the explosion.

Structurally, the main ordnance carrying ring is not the primary load carrying member. Compression loads are reacted by a butting together of the stage skins, tension loads by the tension tie. The joint is designed to react all boost flight loads as well as silo overpressures.

For additional details on the ordnance used in this joint, refer to Section 5.1.

USE FOR TYPEWRITTEN MATERIAL ONLY

USE FOR DRAWING AND HANDWRITING — NO TYPEWRITTEN MATERIAL



DESIGN LOAD TO BE ADDED

AVERAGE DIAMETER - 36.7 IN. O. D.

CROSS SECTIONAL AREA - .688 SQ. IN.

MATERIAL - 2024 AL.

FIGURE 3.2.1-1

REFERENCES: MINUTEMAN ENGINEERING (LGM-307) DWG 25-37645
25-37647

3.2.1.4 BOOSTER SEPARATION JOINT (FIG. 3.2.1-2)

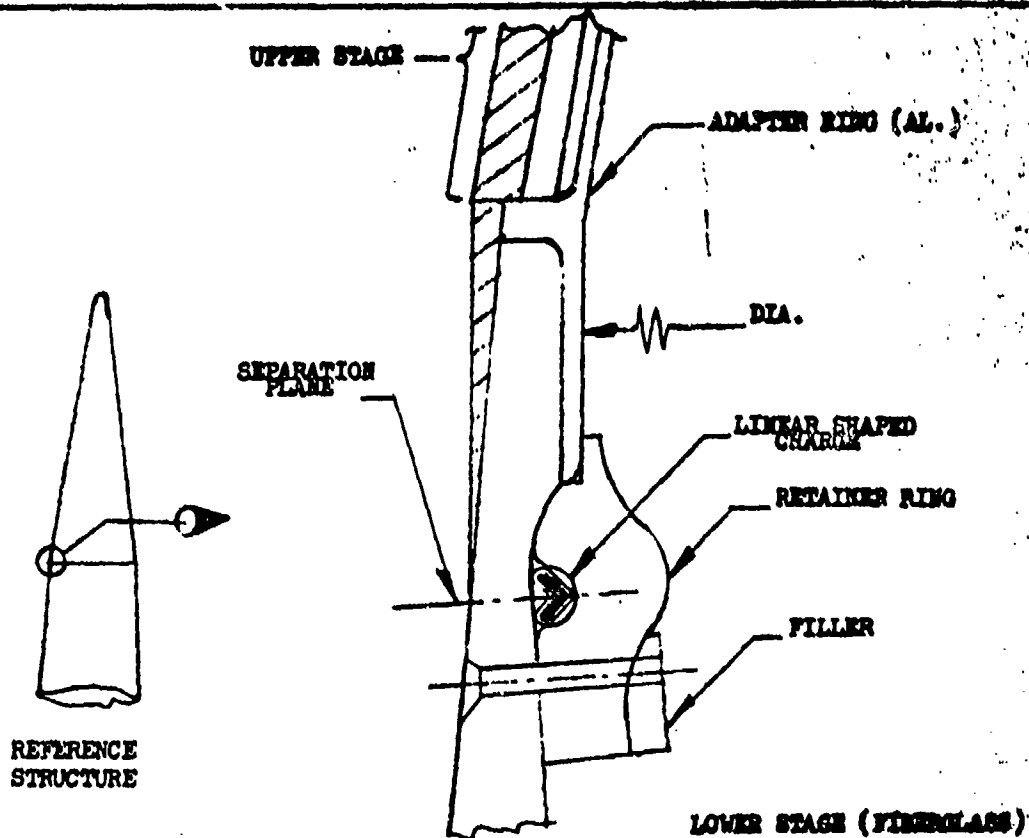
This detail is a section through a circumferential joint used on the HiBEX Missile. It functions to separate the lower (booster) stage from the upper (instrumentation package) stage during flight.

The joint primarily consists of a circumferential retainer ring bolted to the inside of the fiberglass skirt. The ring contains a linear shaped charge designed to direct its energy in an outward direction and thereby sever the fiberglass skirt circumferentially. The retainer ring is not designed to react any loads. It is massive enough however to absorb shock from the explosive charge.

For additional details on the ordnance used in this joint, refer to Section 5.1

USE FOR TYPEPRINTED MATERIAL ONLY

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL



BOOSTER SEPARATION JOINT



CORK

SCALE NONE

| | | | | |
|------------------|---|-----------------------|------------|-------------|
| DESIGN LOAD | - | AXIAL LOAD | = 201K lbs | APPROXIMATE |
| | | BENDING LOAD | = 80 psig | |
| | | (External Pressure) | | |
| AVERAGE DIAMETER | - | 18 IN. OD, | | |
| CROSS SECT. AREA | - | TO BE ADDED | | |
| MATERIAL | - | FIBERGLASS & ALUMINUM | | |

FIGURE 3.2.1-2

REFERENCES: HIBEX PROGRAM DWG 25-39910

3.2.2 LONGITUDINAL JOINTS

These joints are used to separate an interstage or other missile section into a number of parts or segments for removal from the booster in flight. They are longitudinal rather than circumferential and usually function with a circumferential joint (Ref. Fig. 3-1 and Section 3.2.1).

No distinction is made in this section between separation and assembly joints. These joints have one primary function which is separation. They must be assembled, of course, but this is differentiated from the assembly joints discussed elsewhere which are used to assemble missile sections.

3.2.2.1 INTERSTAGE LONGITUDINAL JOINT (FIG. 3.2.2-1)

This joint is typical of those used on the Minuteman missile to split both the Stage 1 - Stage 2 and the Stage 2 and Stage 3 interstage. It is used in conjunction with the circumferential separation joint discussed in Section 3.2.1.1. The dimensions given are the same for both interstages, the only difference being the joint length. Number in parenthesis pertains to the Stage 2 and Stage 3 interstage.

The joint works simultaneously with the skirt removal joint which separates the skirt from the upper booster stage. At the same time, the skirt is split into four sections, effecting both the axial removal from the path of flight, and the radial removal for clearance. The separation impulse providing this function comes from a linear explosive charge. The ring is designed to contain any particle fragmentation with the rubber-like material, PR-1910 (BMS 5-62).

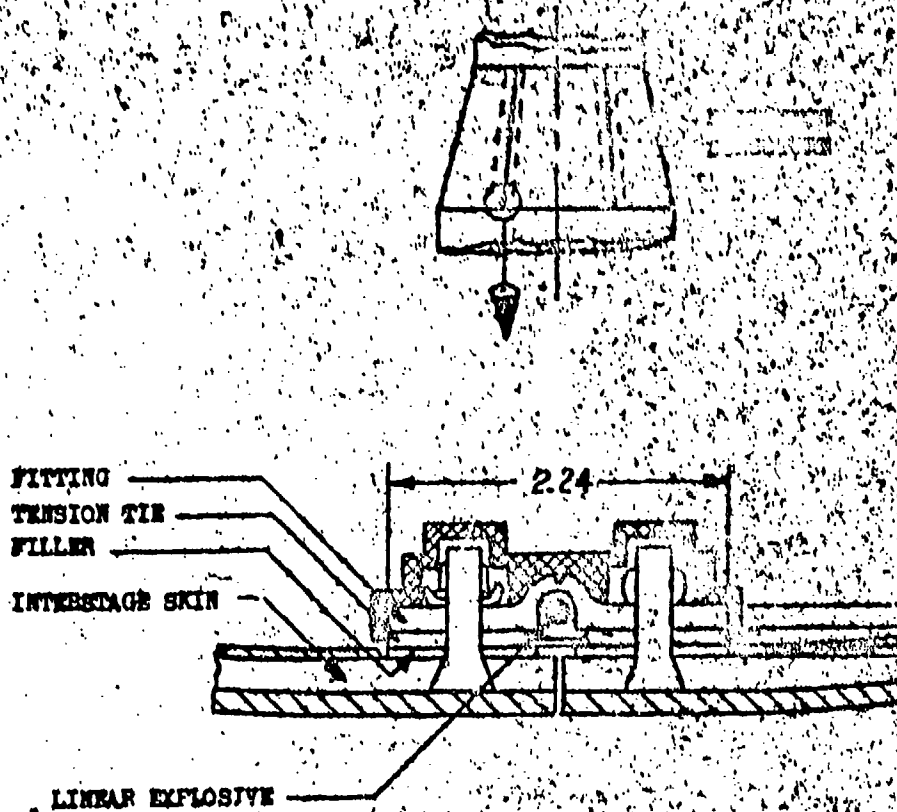
USE FOR TYPEWRITTEN MATERIAL ONLY

The ring is designed to retain all structural integrity throughout flight loads and silo overpressures.

For additional details on the ordnance used in this joint, refer to Section 5.1.

USE FOR TYPE-A T-1A WATERING ONLY

DRAWING AND HANDWRITING - NO TYPEWRITTEN MATERIAL



CORK



7A-1910

1-2 INTERSTAGE LONGITUDINAL JOINT

| | | | |
|--------------------|---|------------------|---------------------|
| DESIGN LOAD | 1 - 2 INTERSTAGE 3000 #/IN. TENSION (STAGING PRESSURE) | | |
| AVERAGE DIAMETER - | (N.A.) | AVERAGE LENGTH - | 42.2 IN. (23.2 IN.) |
| CROSS SECT. AREA - | .641 SQ. IN. | | |
| MATERIAL | - 2024 AL. | | |

FIGURE 3.2.2-1

REFERENCES: MINUTEMAN ENGINEERING DWO: 25-37645
25-37647

3.3 CONCEPT VARIATIONS (BOOSTER STAGE JOINTS)

The joint concept illustrated on Figure 2.2.1-2 was the final configuration of several considered by Missile Structures Organization (2-6455) for the Stage 3 to Post Boost Propulsion System (PBPS) separation joint on Minuteman III. Variations of this final design (referenced above) have been used elsewhere on Minuteman III as booster stage joints (Ref. Fig. 2-3) and to assemble the first and second stages of HIBEX.

The effort which ended in its selection saw thirteen concepts developed after a baseline was established. Figures 3.3-2 and 3.3-3 evaluate the thirteen concepts shown on Figures 3.3-4 through 3.3-13 by comparison to the baseline joint illustrated on Figure 3.3-1.

Figure 3.3-1 identifies the flagnotes on Figures 3.3-2 and 3.3-3.

The baseline, although reduced in diameter, has the same cross sectional configuration as the Stage 3 to Post Boost Vehicle (PBV) joint of Minuteman II from which it was borrowed. Its design loads are based on the requirements of the 1 - 2 Interstage Skirt Removal Joint (part of Fig. A 6750) as follows:

A. First Stage Ignition:

| | |
|----------------------|---------|
| Axial - Lbs. | 222,100 |
| Overpressure - psig | 26.7 |
| Underpressure - psig | 8.0 |

B. Maximum Aerodynamic Loads:

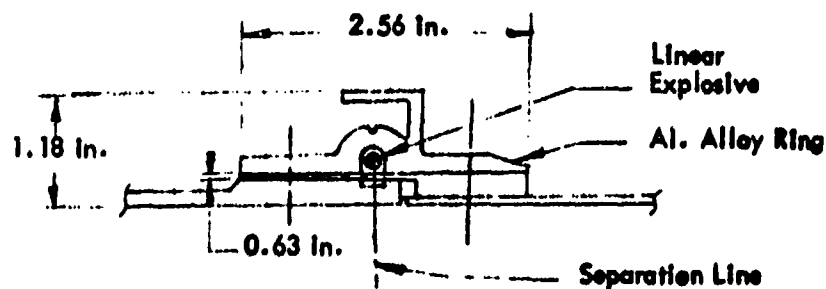
| | |
|------------------------|-----------|
| Bending Moment-in-Lbs. | 2,950,000 |
| Shear - Lbs. | 2,300 |

The baseline characteristics are therefore qualified by similarity to a proven, adequate joint design.

The concepts developed in this effort provide the designer with a variety of design approaches and joint details.

FLAGNOTE KEY TO FIGURES 3.3-2 AND 3.3-3

- 1 COMPARABLE OR LESS THAN G&C UMBILICAL RELEASE.
- 2 REQUIRE APPROXIMATELY 4 - 6 MONTHS TO DEVELOP JOINT AND 5 MONTHS MINIMUM TO QUALIFY THE ORDNANCE DEVICE.
- 3
 - 1. LOCAL AREAS AROUND RELEASE PROVISIONS DO NOT CARRY COMPRESSION OR TENSION LOADS. DISTRIBUTION INTO HPC FWD SKIRT OR PBPS MAY BE PROBLEM.
 - 2. DESIGN OF TENSION BAND TO PROVIDE REQUIRED JOINT STIFFNESS MAY PRESENT PROBLEMS. (I.E., PRE-LOAD, THERMAL LOADS, ETC.)
- 4 ELECTRICAL INTERFACE COMPATIBLE WITH MGS.
- 5 MECHANICAL INTERFACE COMPATIBLE WITH STAGE 3 MOTOR & PBPS.
- 6 MECHANICAL INTERFACE NOT COMPATIBLE WITH APPROPRIATE PBPS CONFIGURATION.
- 7 FOR BASELINE DESCRIPTION SEE PARAGRAPH 3.3 AND THE ILLUSTRATION BELOW:







NOTE:

G&C = Guidance & Control
HPC = Hercules Power Company
PBPS = Post Boost Propulsion System
MGS = Missile Guidance Set

Figure 3.3-1

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

CONFIGURATION

| | DESCRIPTION | SHOCK EFFECTS | WEIGHT (Lb) | ENVELOPE |
|----|---|--|----------------|--|
| | <p>BASE LINE </p> <p>INTERNAL FRACTURING LINEAR EXPLOSIVE JOINT SYSTEM</p> |  | 23.0 | PER BOEING LAYOUT MDUS LO-68 REV. "A DTD 11-17-65 |
| 1. | BALL LOCK RELEASE JOINT (10 EQUALLY SPACED) | VERY LOW | 31.5 | EXCEEDS ENVELOPE ALL AROUND |
| 2. | INTERNAL BAND SEPARATION JOINT (SOLID BAND WITH ORDNANCE RELEASED OR ORDNANCE ACTUATED RELEASE MECHANISM) | VERY LOW | 22.1 | EXCEEDS ENVELOPE ALL AROUND |
| 3. | EXTERNAL TENSION BAND SEPARATION JOINT (SOLID BAND WITH EXPLOSIVE BOLT RELEASE SYSTEM) |  | 16.0 | EXCEEDS ENVELOPE LOCALLY |
| 4. | EXTERNAL TENSION BAND SEPARATION JOINT (SEPARATE BAND WITH TENSION SHOES WITH EXPLOSIVE BOLT RELEASE SYSTEM) |  | 15.6 | EXCEEDS ENVELOPE LOCALLY |
| 5. | EXTERNAL TENSION BAND SEPARATION JOINT (SEPARATE BAND WITH TENSION SHOES WITH EXPLOSIVE NUT RELEASE SYSTEM) |  | 16.0 | EXCEEDS ENVELOPE LOCALLY |
| 6. | EXTERNAL TENSION BAND SEPARATION JOINT (SEPARATE BAND WITH TENSION SHOES WITH EXPLOSIVE TURNBUCKLE RELEASE SYSTEM) |  | 15.6 | EXCEEDS ENVELOPE LOCALLY |

NOTE: FOR KEY TO FLAGNOTES SEE FIGURE 3.3-1

| WEIGHT (Lbs) | ENVELOPE | INTER- FACE | SCHED- ULE | STRUCTURAL | RELIABILITY | ORDNANCE QUALIFICATION |
|-----------------|--|----------------|---------------|--|-------------|--|
| 23.0 | PER BOEING LAYOUT MDUS- LO-68 REV. "A" DTD 11-17-65 | 4 5 | — | — | .9999 | QUALIFIED BY SIMILARITY |
| 31.5 | EXCEEDS ENVELOPE ALL AROUND | 4 6 | 2 | NEED VERIFICA- TION ON LOAD DISTRIBUTION INTO HPC FWD SKIRT | LOWER | QUALIFICATION OF ORDNANCE ACTUATED DEVICE REQ'D. |
| 22.1 | EXCEEDS ENVELOPE ALL AROUND | 4 5 | 2 | RELEASE LINKAGE AND BAND DESIGN WITH REGARD TO JOINT STIFFNESS MAY PRESENT PROBLEMS | SIMILAR | ↑ |
| 16.0 | EXCEEDS ENVELOPE LOCALLY | 4 5 | 2 | 3 | SIMILAR | |
| 15.6 | EXCEEDS ENVELOPE LOCALLY | 4 5 | 2 | 3 | SIMILAR | |
| 16.0 | EXCEEDS ENVELOPE LOCALLY | 4 5 | 2 | 3 | SIMILAR | |
| 15.6 | EXCEEDS ENVELOPE LOCALLY | 4 5 | 2 | 3 | SIMILAR | |
| | | | | | | ↓ |




FIGURE 3.3-2

| ED- A | STRUCTURAL | RELIABILITY | ORDNANCE QUALIFICATION | ORDNANCE LOADING |
|----------|---|-------------|--|---------------------|
| | | 9999 | QUALIFIED BY SIMILARITY | EXTERNAL LOADING |
| > | NEED VERIFICATION ON LOAD DISTRIBUTION INTO MPC FWD SKIRT | LOWER | QUALIFICATION OF ORDNANCE ACTUATED DEVICE REQ'D. | INTERNAL LOADING |
| > | RELEASE LINKAGE AND BAND DESIGN WITH REGARD TO JOINT STIFFNESS MAY PRESENT PROBLEMS | SIMILAR | ↑ ↓ | INTERNAL LOADING |
| > | 3 | SIMILAR | | EXTERNAL LOADING |
| > | 3 | SIMILAR | | EXTERNAL LOADING |
| > | 3 | SIMILAR | | EXTERNAL LOADING |
| > | 3 | SIMILAR | | EXTERNAL LOADING |

FIGURE 3.3-2

SHT. #7

CONSIDERATION

| | DESCRIPTION | SHOCK EFFECTS | WEIGHT (LBS) | ENVELOPE |
|-----|--|--|-----------------|---|
| 7. | EXTERNAL TENSION BAND SEPARATION JOINT (SEPARATE BAND WITH TENSION SHOES WITH SHAPE CHARGE RELEASE SYSTEM) |  | 16.8 | WITHIN ENVELOPE |
| 8. | EXPLOSIVE BOLT RELEASE SYSTEM (10 EQUALLY SPACED) |  | 24.0 | EXCEEDS ENVELOPE ALL AROUND |
| 9. | EXPLOSIVE NUT RELEASE SYSTEM (10 EQUALLY SPACED) |  | 24.0 | EXCEEDS ENVELOPE ALL AROUND |
| 10. | ORDNANCE RELEASED BONDED SEPARATION JOINT | LESS BECAUSE OF SMALLER CHARGE & NO BREAKING OF METAL | 12.60 | WITHIN ENVELOPE |
| 11. | REVISED LINEAR ORDNANCE CHARGE JOINT (BASED ON LOCKHEED REPORT) | LESS BECAUSE OF SMALLER CHARGE & REVISED JOINT | 16.6 | .60 LONGER THAN PRESENT ENVELOPE ON SKIN LEG ONLY |
| 12. | REVISED LINEAR ORDNANCE CHARGE JOINT USING SMALL CHARGE (5 - 10 GR/FT) | LESS BECAUSE OF SMALLER CHARGE | 12.9 | WITHIN ENVELOPE |
| 13. | SHAPED CHARGE ORDNANCE SYSTEM | LESS BECAUSE OF SMALLER CHARGE. THE FORCE IS DIRECTED Laterally | 11.1 | WITHIN ENVELOPE |

NOTE: FOR KEY TO FLAGNOTES SEE FIGURE 3.3-1

T

1

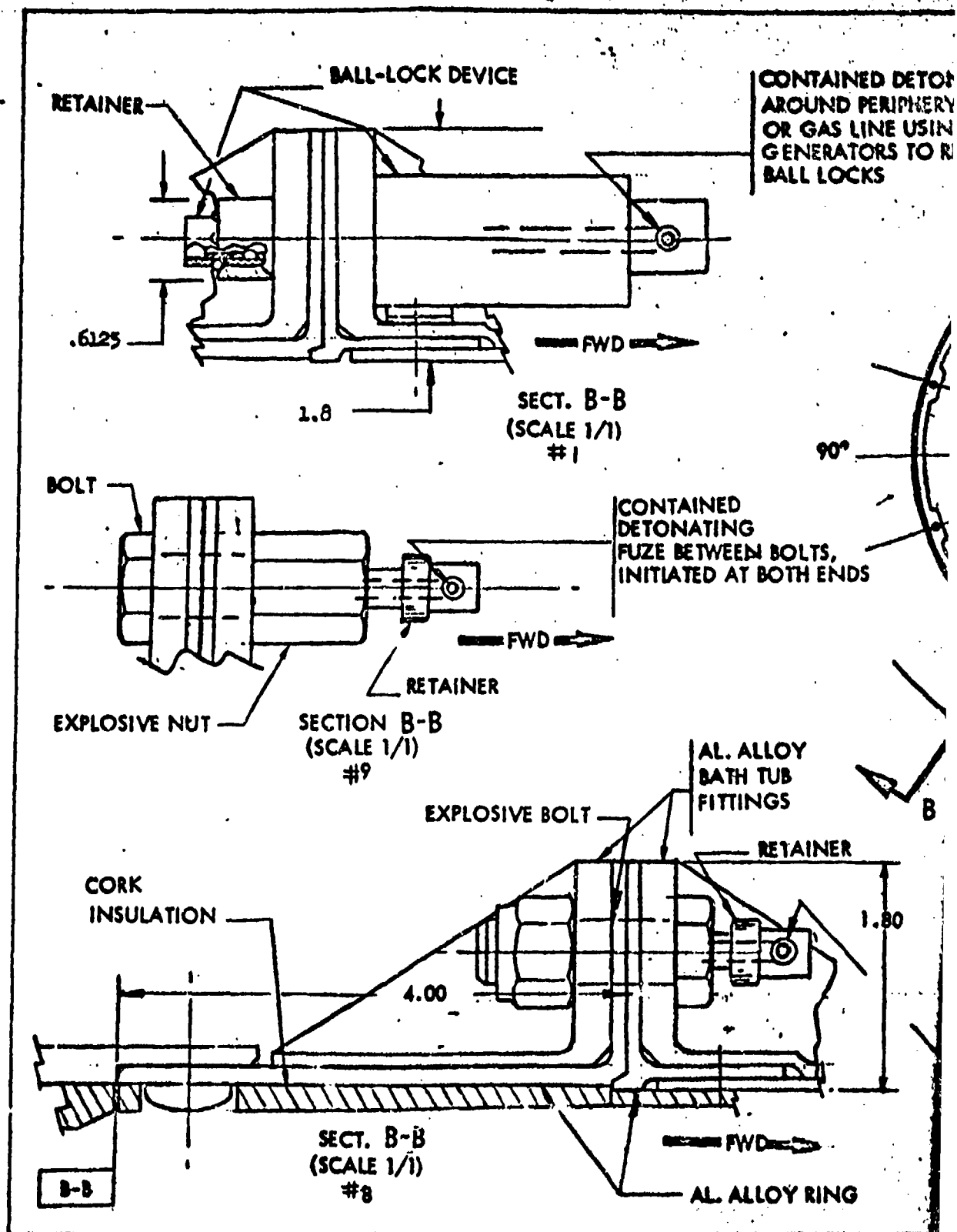
| HEIGHT (S) | ENVELOPE | INTER-FACE | SCHEDULE | STRUCTURAL | RELIABILITY | ORDNANCE QUALIFICATION |
|------------|---|------------|----------|---|-------------|--|
| 5.8 | WITHIN ENVELOPE | 4 5 | 2 | 3 | SIMILAR | QUALIFICATION OF ORDNANCE ACTUATED DEVICE REQ'D. |
| 1.0 | EXCEEDS ENVELOPE ALL AROUND | 4 6 | 2 | NEED VERIFICATION ON LOAD DISTRIBUTION INTO HPC FWD SKIRT | LOWER | |
| 1.0 | EXCEEDS ENVELOPE ALL AROUND | 4 6 | 2 | NEED VERIFICATION ON LOAD DISTRIBUTION INTO HPC FWD SKIRT | LOWER | |
| .60 | WITHIN ENVELOPE | 4 5 | 2 | EVALUATION OF STRUCTURAL BOND ON TENSION MEMBER | SIMILAR | |
| .6 | .60 LONGER THAN PRESENT ENVELOPE ON SKIN LEG ONLY | 4 5 | 2 | NO PROBLEMS | SIMILAR | |
| .9 | WITHIN ENVELOPE | 4 5 | 2 | NO PROBLEMS | SIMILAR | |
| 1 | WITHIN ENVELOPE | 4 5 | 2 | NO PROBLEMS | SIMILAR | |

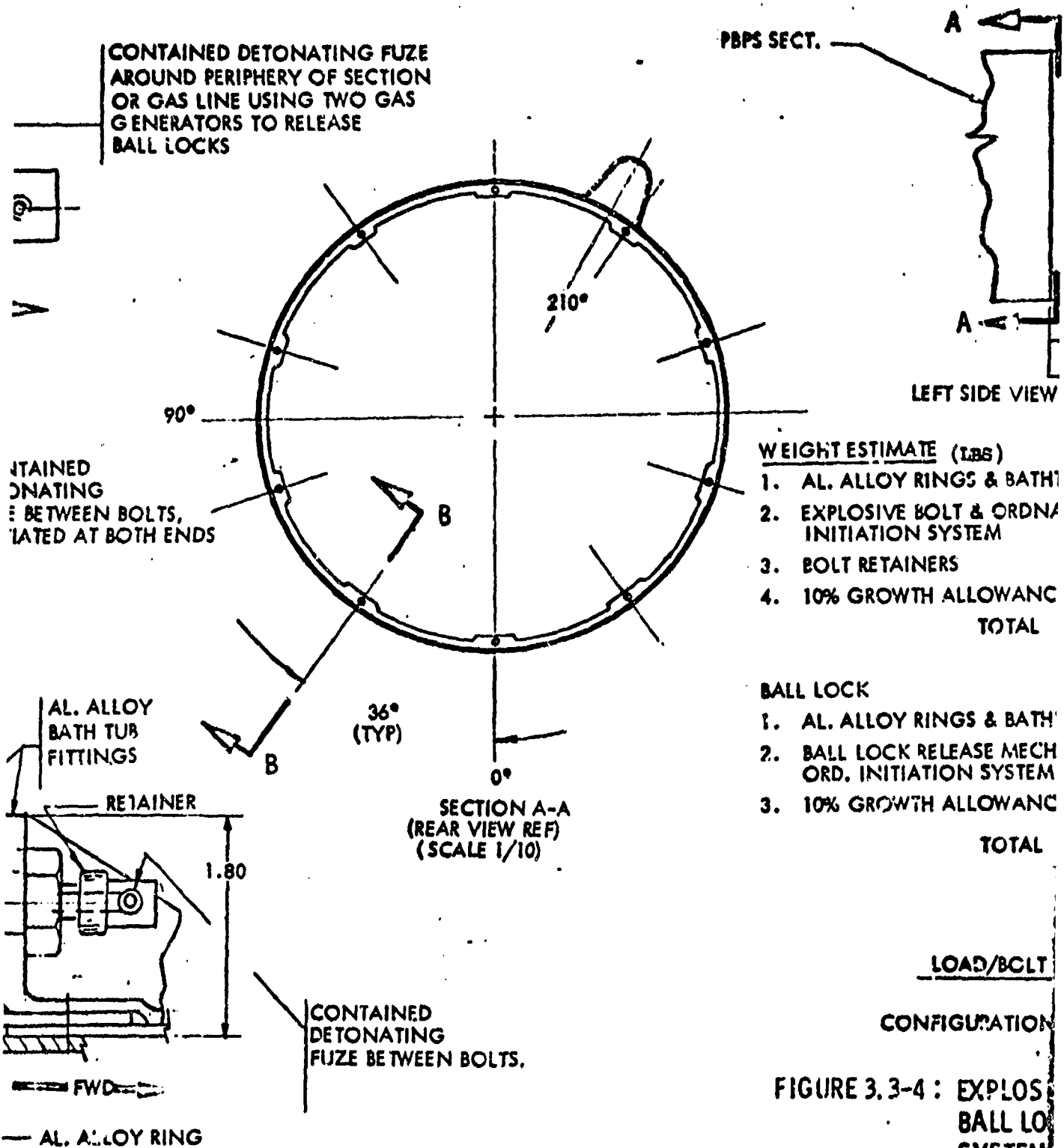
FIGURE 3.3-1

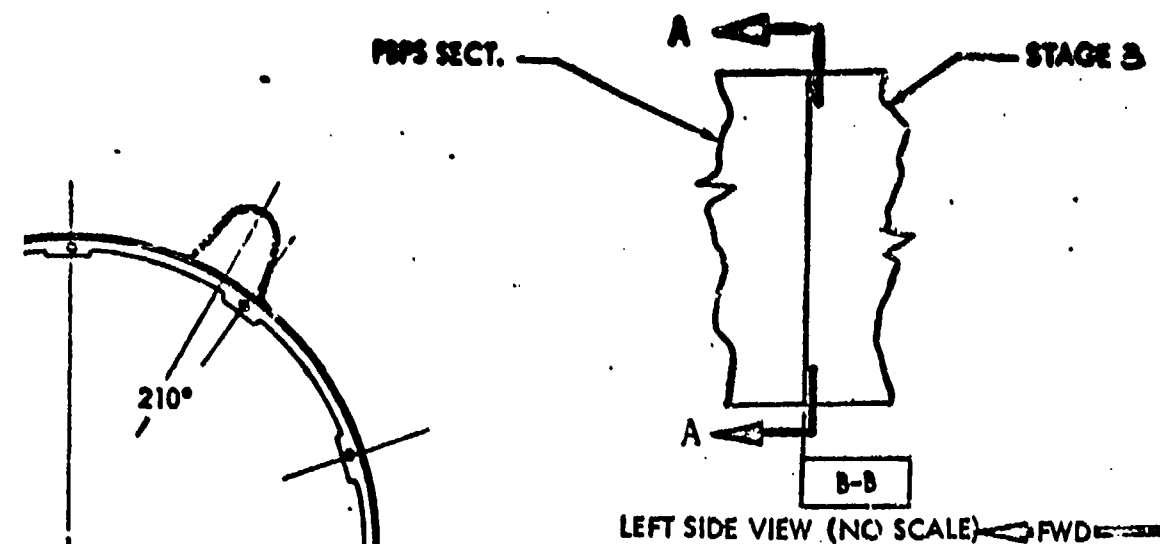
| AL | RELIABILITY | ORDNANCE QUALIFICATION | ORDNANCE LOADING |
|------------------------|-------------|---|------------------------------------|
| | SIMILAR | QUALIFICATION OF ORDNANCE ACTUATED DEVICE REQD. | INTERNAL LOADING |
| ICA- DAD ON T | LOWER | | INTERNAL LOADING |
| ICA- DAD ON T | LOWER | | INTERNAL LOADING |
| ON IRAL MBER | SIMILAR | | INTERNAL LOADING |
| MS | SIMILAR | | EXTERNAL OR INTERNAL LOADING |
| MS | SIMILAR | | EXTERNAL LOADING |
| MS | SIMILAR | | INTERNAL LOADING |

FIGURE 3.3-1

SHY. 48







WEIGHT ESTIMATE (LBS)

| | |
|--|-------------|
| 1. AL. ALLOY RINGS & BATHTUB FITTINGS | 15.2 |
| 2. EXPLOSIVE BOLT & ORDNANCE INITIATION SYSTEM | 4.0 |
| 3. BOLT RETAINERS | 3.5 |
| 4. 10% GROWTH ALLOWANCE | 2.3 |
| TOTAL | 24.0 |

BALL LOCK

| | |
|---|-------------|
| 1. AL. ALLOY RINGS & BATHTUB FITTINGS | 17.5 |
| 2. BALL LOCK RELEASE MECHANISM & ORD. INITIATION SYSTEM | 11.3 |
| 3. 10% GROWTH ALLOWANCE | 2.7 |
| TOTAL | 31.5 |

SECTION A-A
(VIEW REF)
SCALE 1/10)

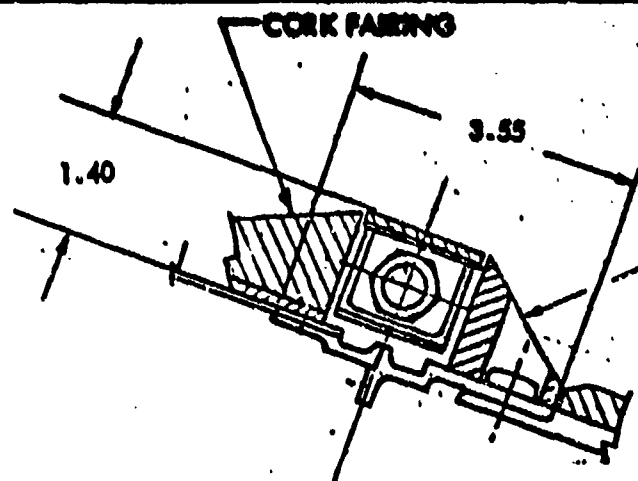
LOAD/BOLT 7500[#]

CONFIGURATION 1, 8, & 9

BOLTS.

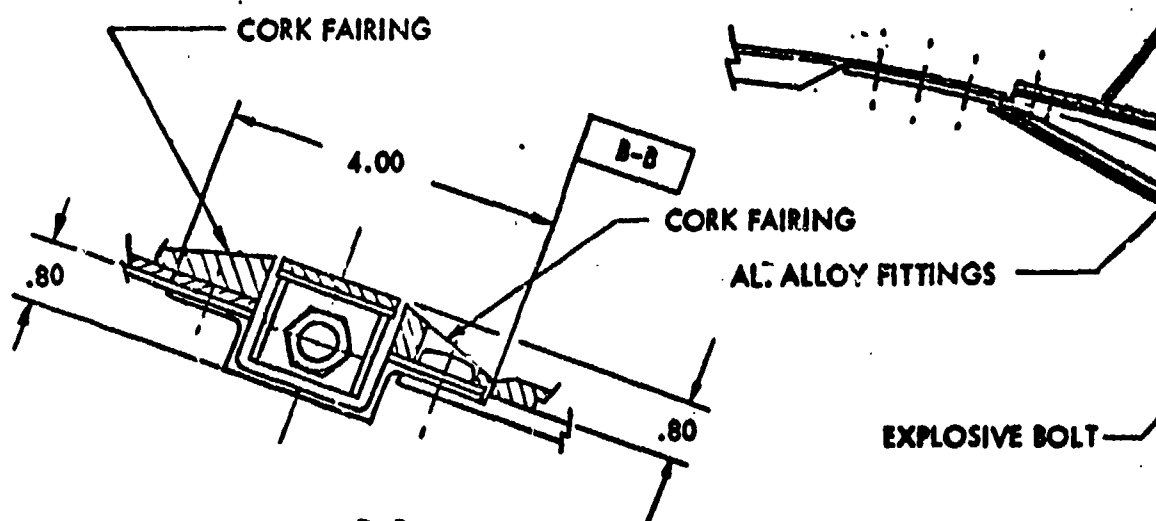
FIGURE 3.3-4 : EXPLOSIVE BOLT, NUT & BALL LOCK SEPARATION SYSTEM

SHEET 49



SECTION D-D
(SCALE 1/2)

FWD

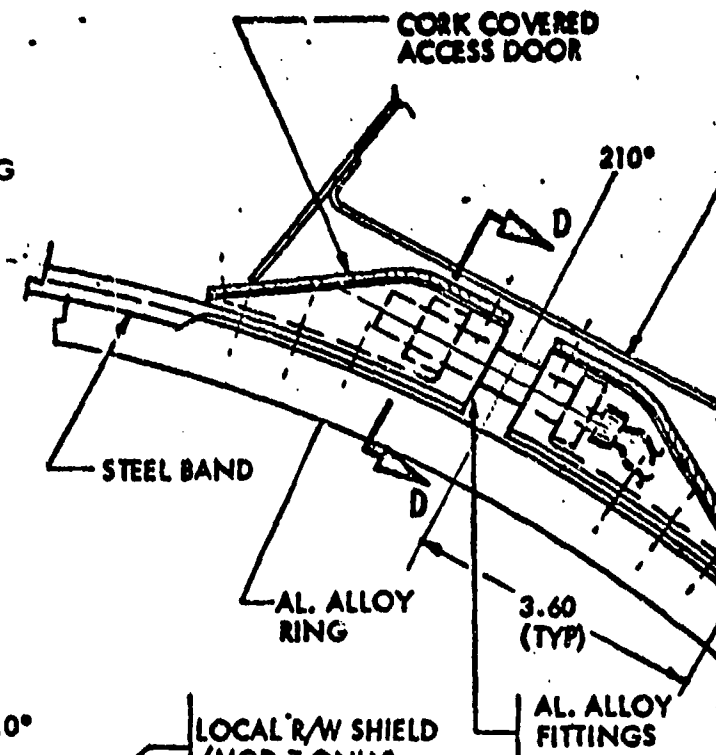
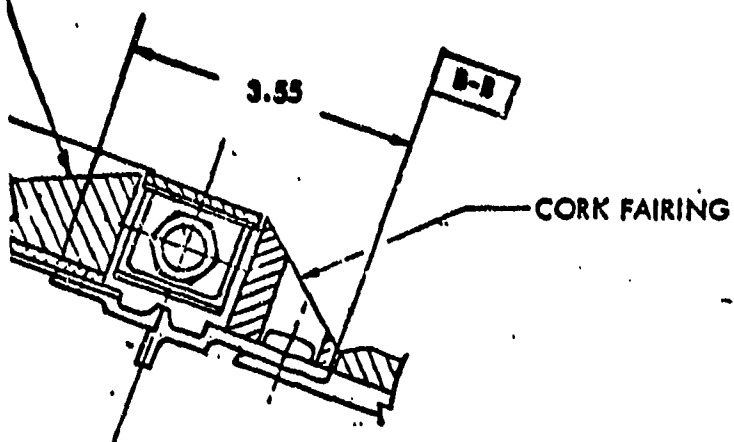


SECTION D-D
(SCALE 1/2)

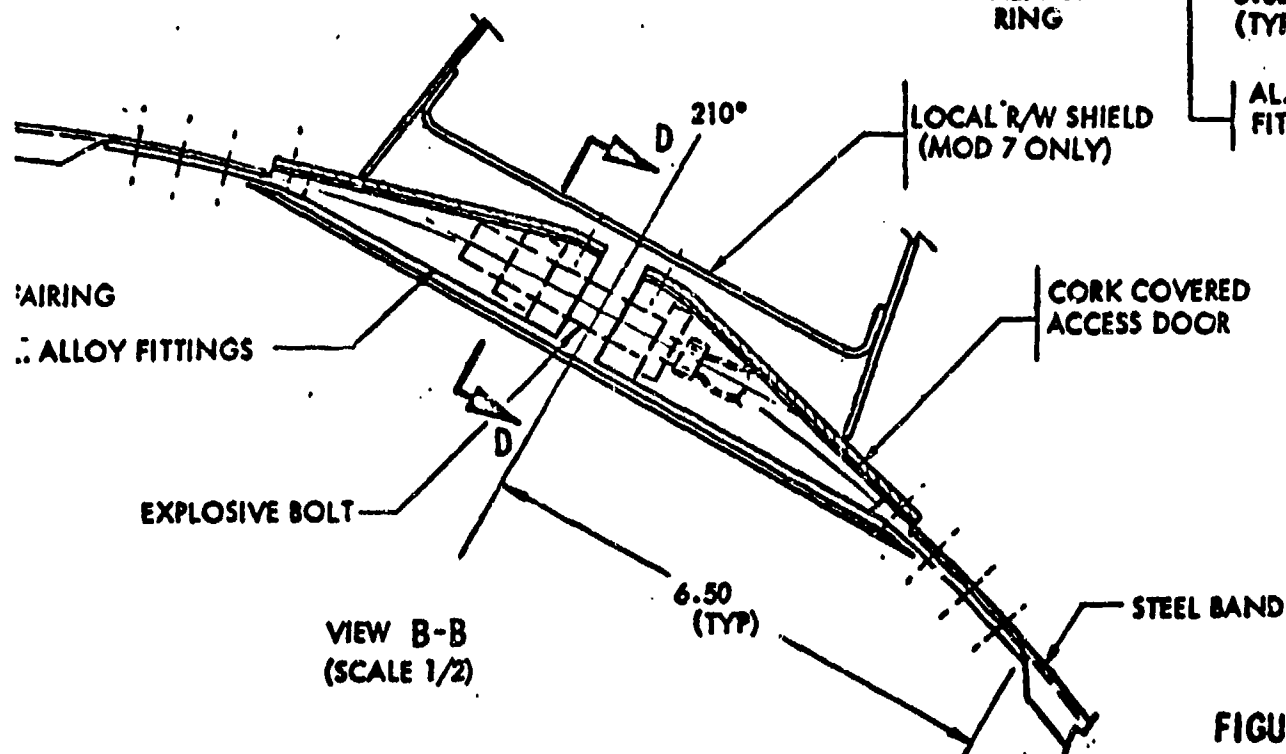
FWD

VIEW B
(SCALE

CORK FAIRING



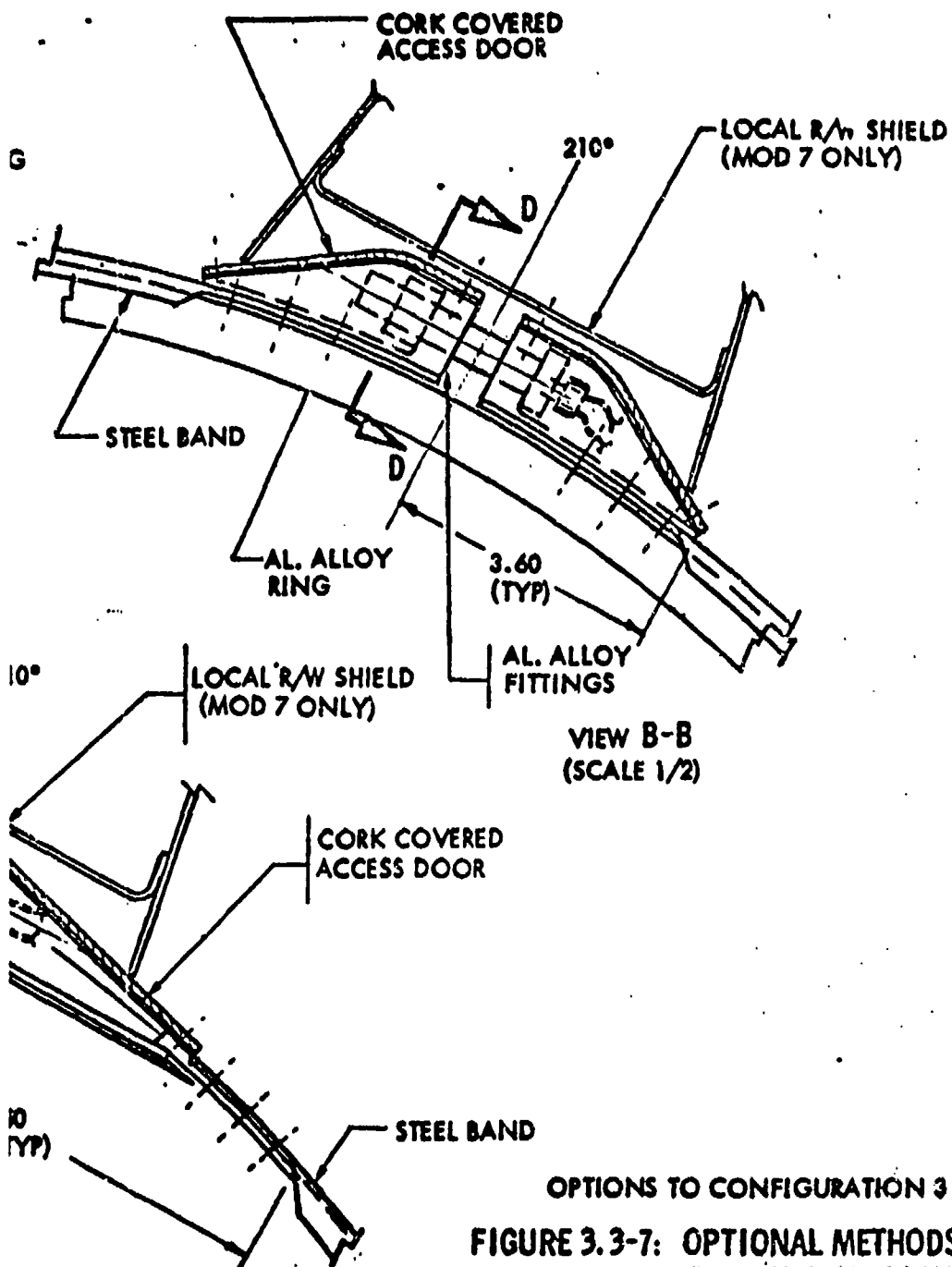
VIEW B-B
(SCALE 1/)



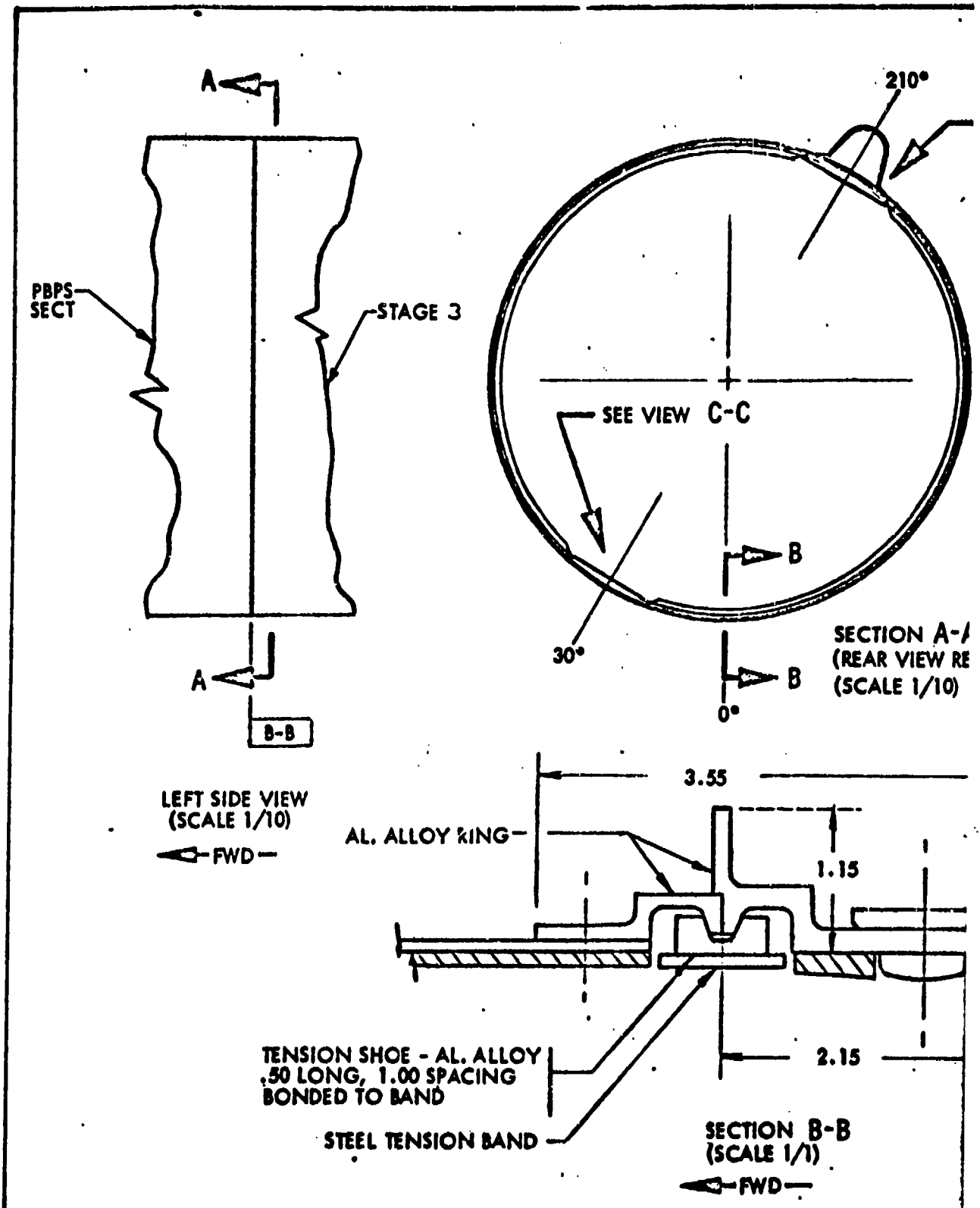
OPTIONS 1

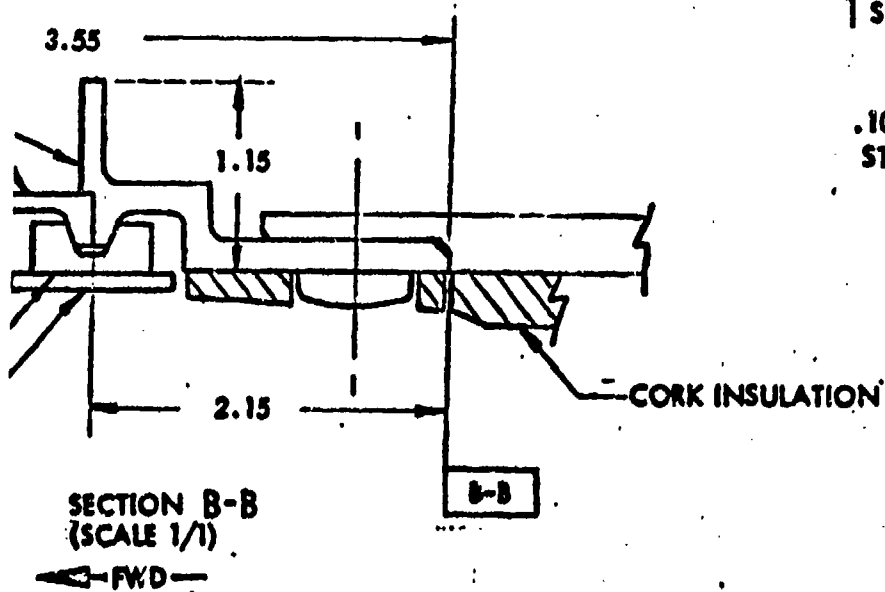
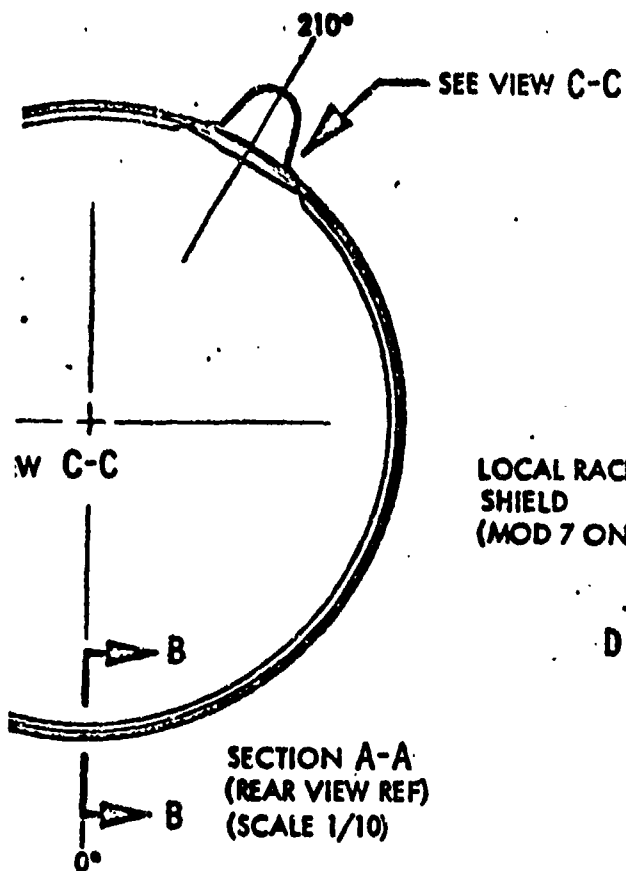
FIGURE 3.3-7:





OPTIONS TO CONFIGURATION 3
FIGURE 3.3-7: OPTIONAL METHODS
EXTERNAL TENSION
BAND SEPARATION
SYSTEM





LOCAL RACEWAY
SHIELD
(MOD 7 ONLY)

SECTION D-D
(SCALE 1/2)

1/2 DIA EXPLOSIVE BOLT

210°

4.70
(TYP)

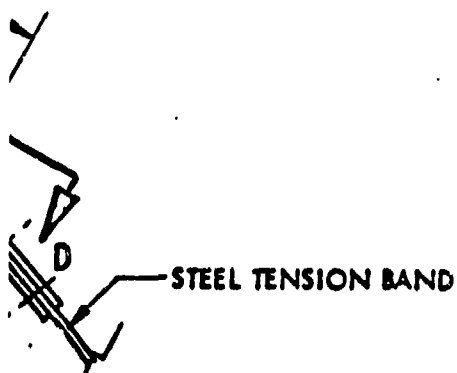
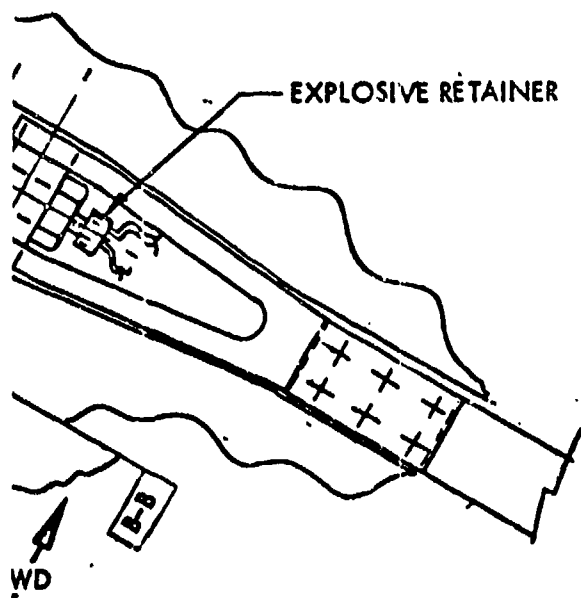
3/4 DIA.
STL. PIN

.10 STL
STRAP

VIEW C-C
(SCALE 1/2)

FWD

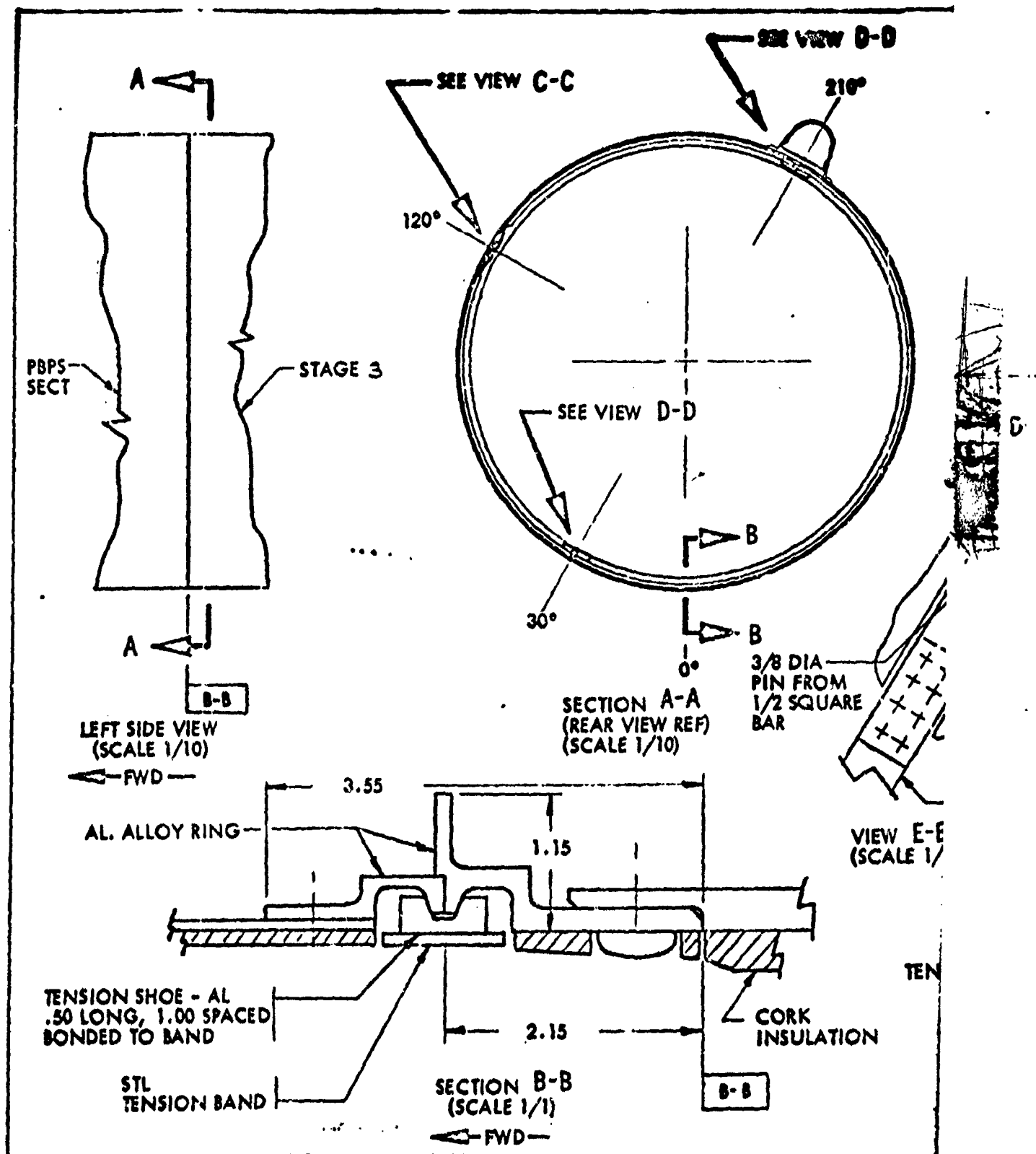
D

WEIGHT ESTIMATE (LBS)

| | |
|------------------------------------|--------------|
| BAND & SHOES | 3.40 |
| FITTINGS ON BAND | .70 |
| EXPLOSIVE BOLT & RETAINER | 1.00 |
| RING STRUCTURE | 7.40 |
| LOCAL FITTINGS @ EXPLOSIVE BOLT | 1.70 |
| 10% GROWTH ALLOWANCE | 1.40 |
| TOTAL WEIGHT | 15.60 |

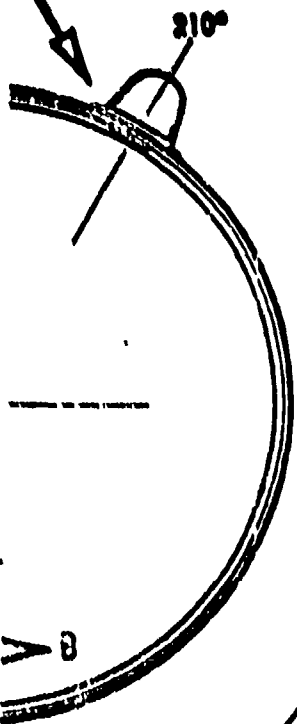
CONFIGURATION 4, 5, & 6

**FIGURE 3.3-8: EXTERNAL TENSION
BAND SEPARATION
SYSTEM**SHEET 53



US 4832 1435 07-C 4.65

SEE VIEW D-D



DETONATOR

MAG SKIN

CONNECTOR

FITTING

SECTION
(SCALE

FW

V B

V B

3/8 DIA
PIN FROM
1/2 SQUARE
BAR

3/8 DIA
BOLT
1/2 HEX BAR

STRAP
.10 STL
STRAP

TENSION BAND

VIEW E-E
(SCALE 1/2)

TENSION
SHOE

TENSION BAND

VIEW C-C
(SCALE 1/2)

5.0
(TYP)

120°

RING

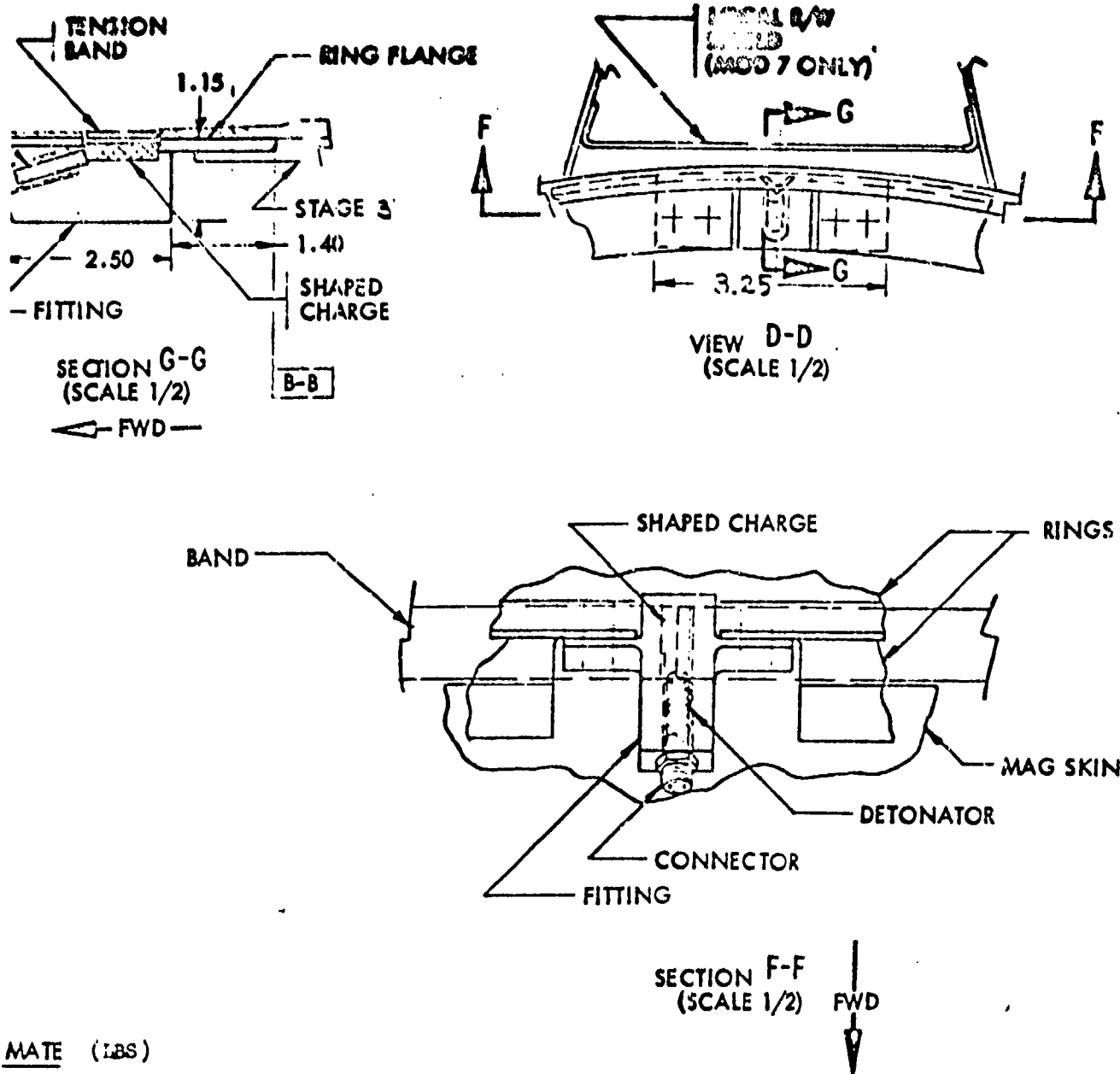
CORK
INSULATION

D-D

WEIGHT ESTIMATE (LBS)

BAND & SHOES
DETONATORS, CONNECTOR
SHAPE CHARGE FTG A
TURNBUCKLE ASSY
RING STRUCTURE
LOCAL FITTINGS AT TURN
10% GROWTH ALLOWANCE

TOTAL WEIGHT



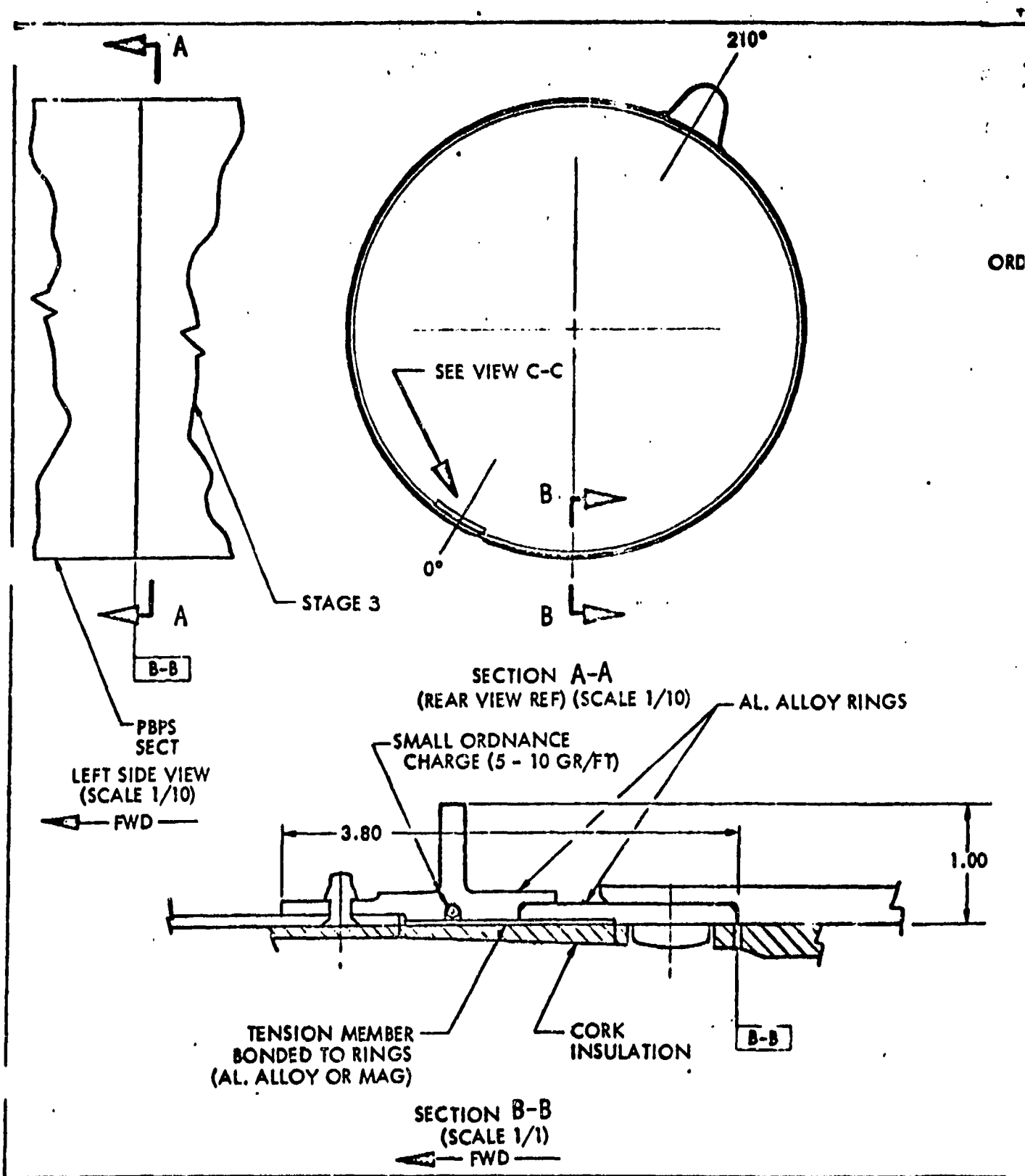
MATE (LBS)

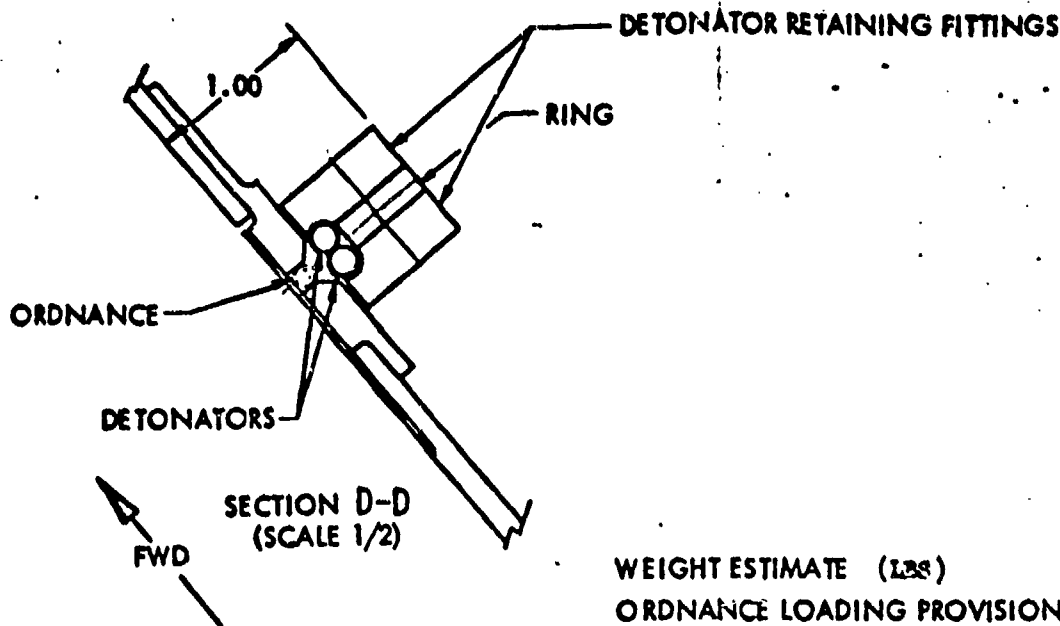
| | |
|--------------------|------|
| DES | 4.1 |
| IS, CONNECTORS & | |
| ARGE FTG ASSY | 2.0 |
| E ASSY | 1.0 |
| TURE | 6.5 |
| NGS AT TURNBUCKLES | 1.7 |
| H ALLOWANCE | 1.5 |
| TOTAL WEIGHT | 16.8 |

CONFIGURATION 7

FIGURE 3.3-9: EXTERNAL TENSION BAND SEPARATION SYSTEM

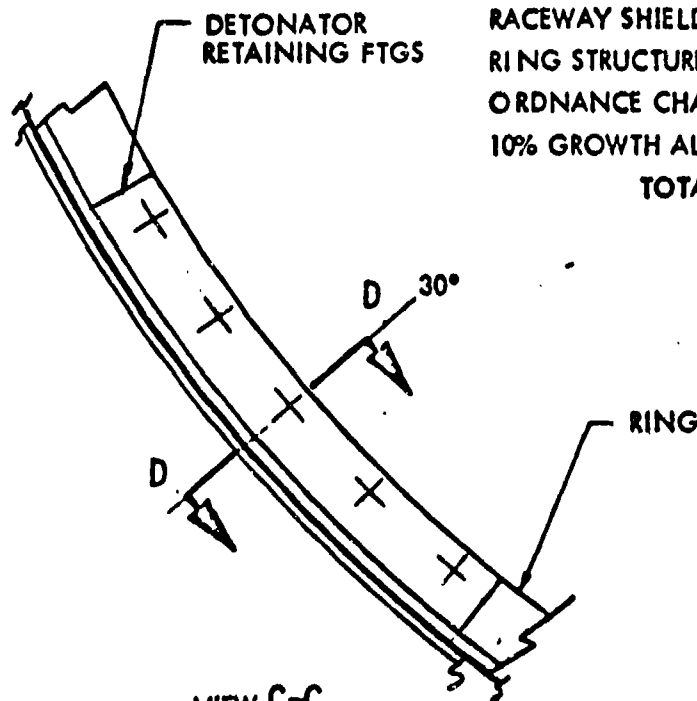
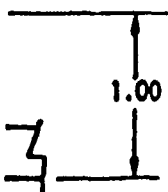
SHEET 59





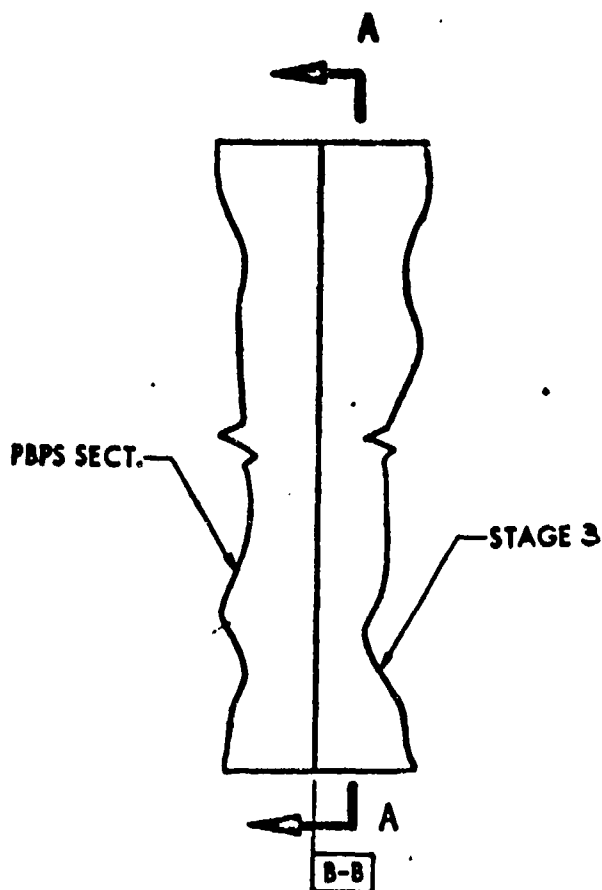
| WEIGHT ESTIMATE (LBS) | |
|-----------------------------|-------------|
| ORDNANCE LOADING PROVISIONS | .30 |
| RACEWAY SHIELD | .20 |
| RING STRUCTURE | 9.50 |
| ORDNANCE CHARGE | 1.40 |
| 10% GROWTH ALLOWANCE | <u>1.20</u> |
| TOTAL WEIGHT | 12.60 |

IGS



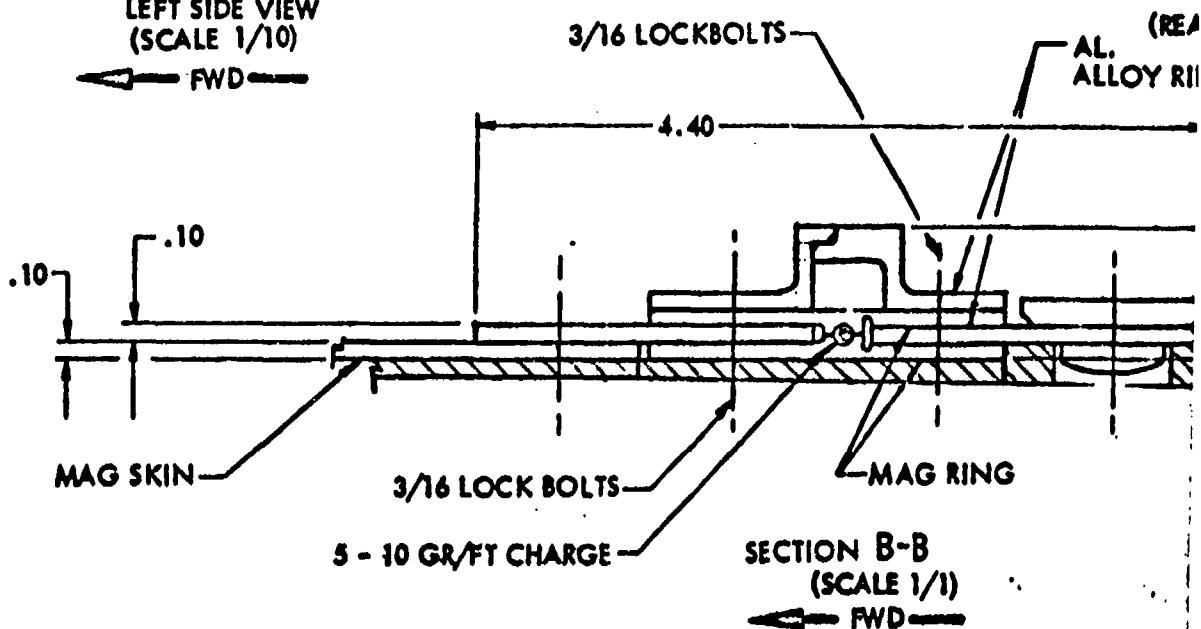
VIEW C-C
(SCALE 1/2)
(DETONATOR LOADING AREA)

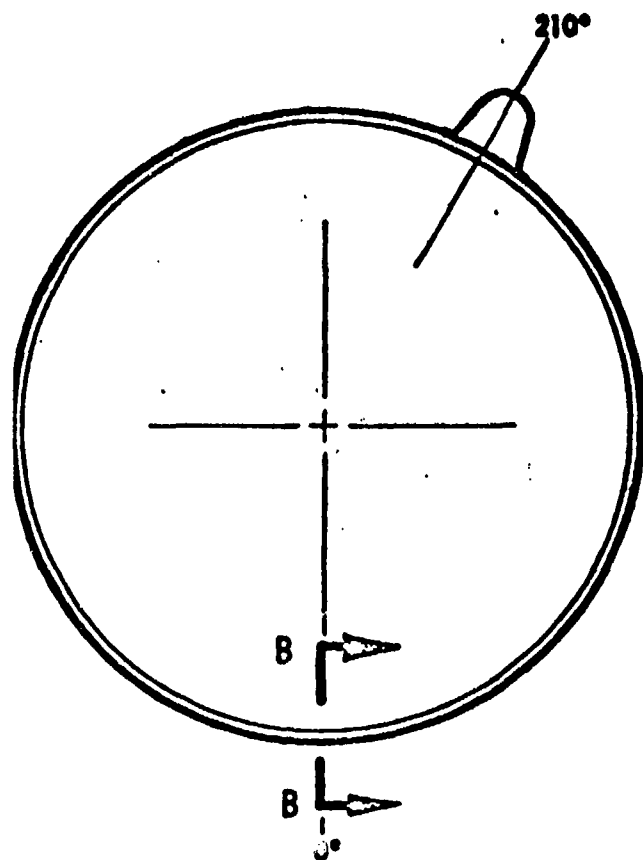
CONFIGURATION 10
FIGURE 3.3-10: ORDNANCE RELEASED
BONDED SEPARATION
JOINT



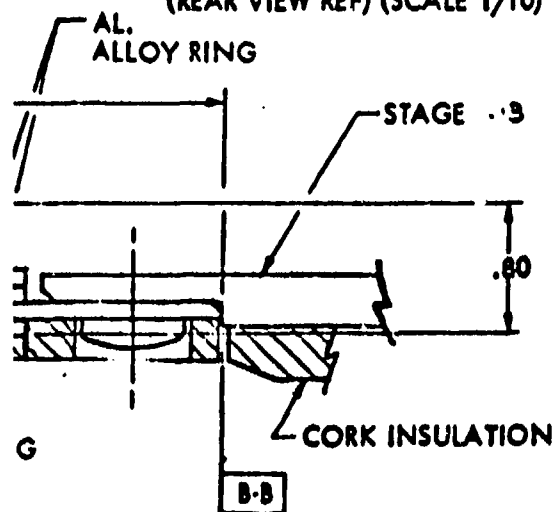
LEFT SIDE VIEW
(SCALE 1/10)

← FWD →





SECTION A-A
(REAR VIEW REF) (SCALE 1/10)



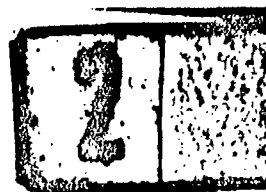
WEIGHT ESTIMATE (LBS)

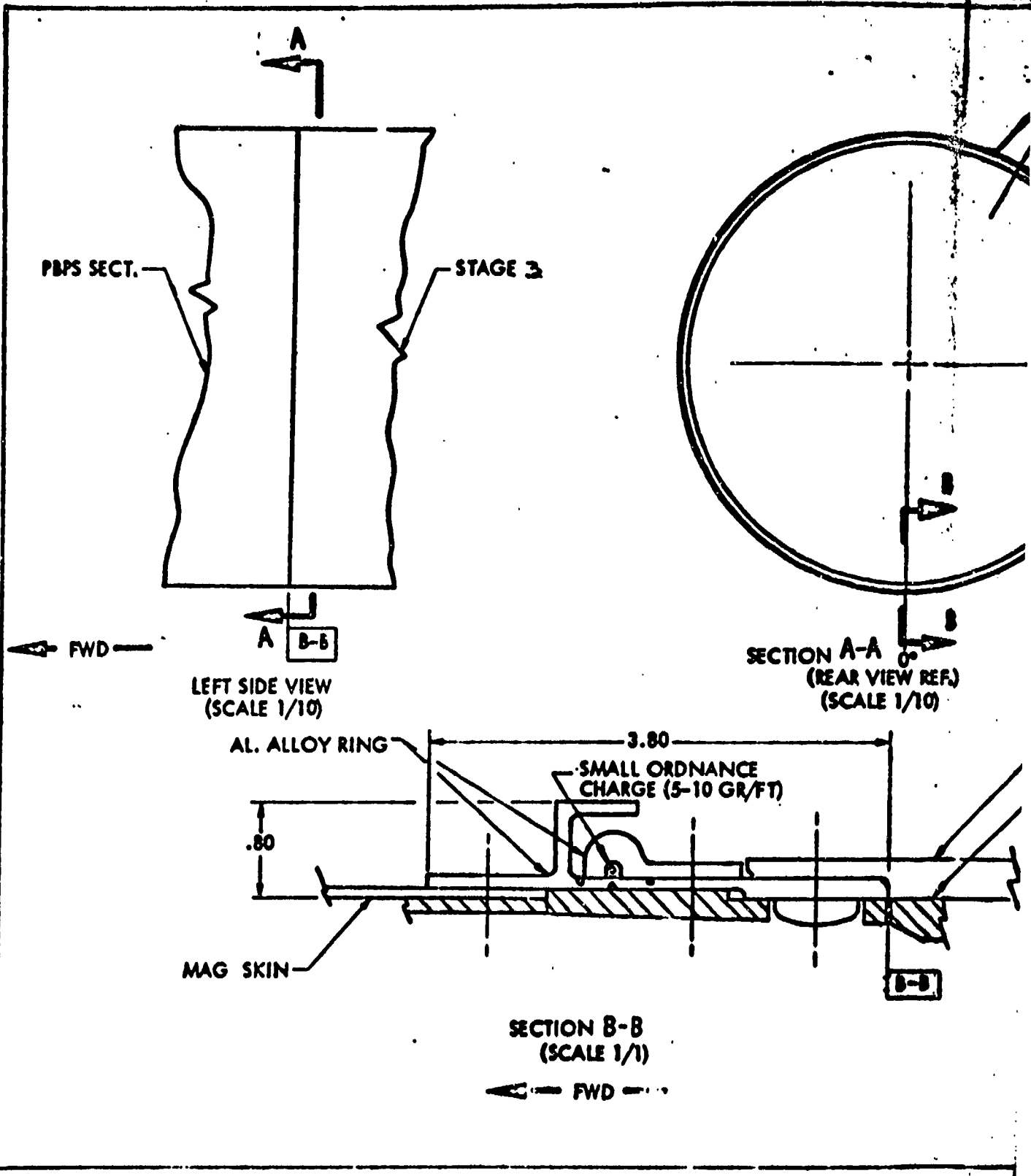
| | |
|-----------------------|------------|
| AL. ALLOY RINGS | 8.6 |
| MAG RINGS | 3.3 |
| ORDNANCE CHARGE | .4 |
| LOCK BOLTS | 2.0 |
| ORDNANCE LOADING DOOR | .8 |
| 10% GROWTH ALLOWANCE | <u>1.5</u> |
| TOTAL WEIGHT | 16.6 |

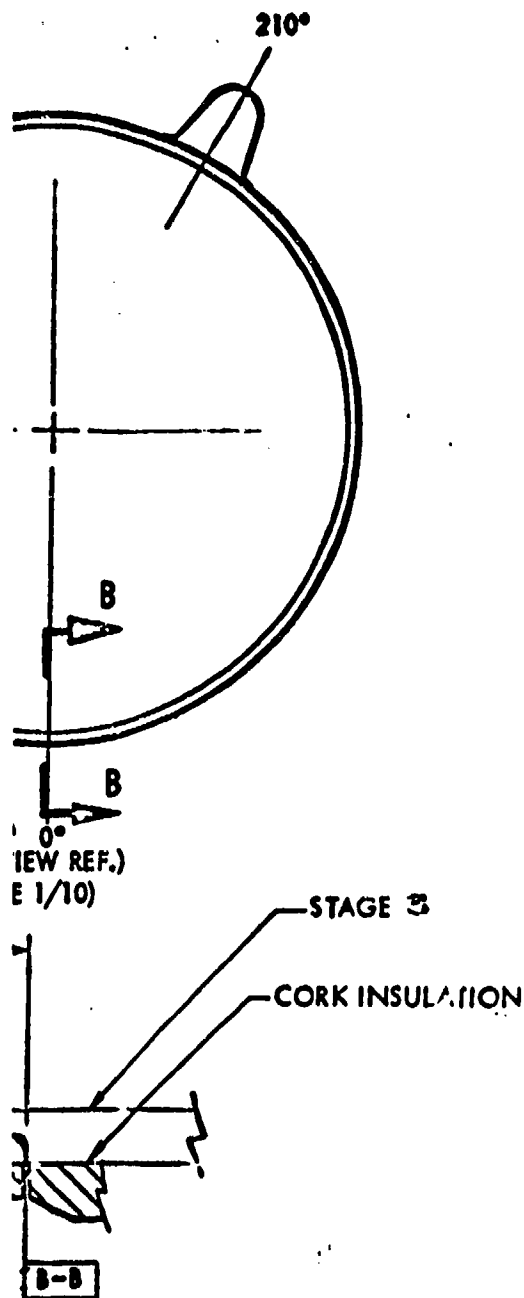
CONFIGURATION 11

FIGURE 3.3-11: LOW SHOCK
ORDNANCE SEPARATION
SYSTEM

SHEET 56







| <u>WEIGHT ESTIMATE</u> (LBS) | |
|------------------------------|------------|
| RING STRUCTURE | 9.5 |
| ORDNANCE & LOADING PROV. | .8 |
| AFT LOCK BOLTS | 1.4 |
| 10% GROWTH ALLOWANCE | <u>1.2</u> |
| TOTAL WEIGHT | 12.9 |

CONFIGURATION 12
FIGURE 3.3-12: REVISED LINEAR ORDNANCE
SEPARATION SYSTEM

SHEET 57

PBPS SECT.

STAGE 3



LEFT SIDE VIEW
(SCALE 1/10)

← FWD →

MAG SKIN

1.10

MAG RING

7 GR/FT SHAPED CHARGE

AL. ALLOY RING

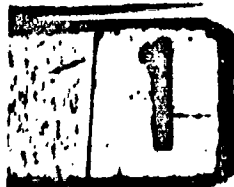
3.60

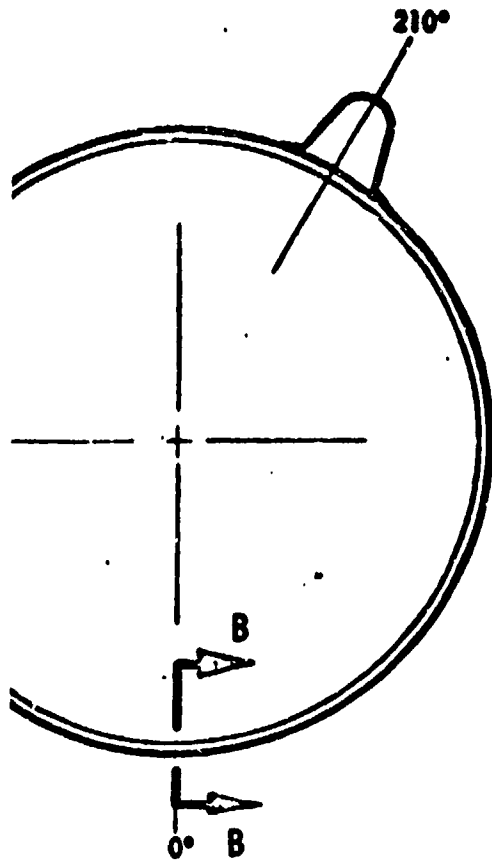
FOAM SHOCK
ABSORBER

SECTION
(REAR VIEW)
(SCALE 1/1)

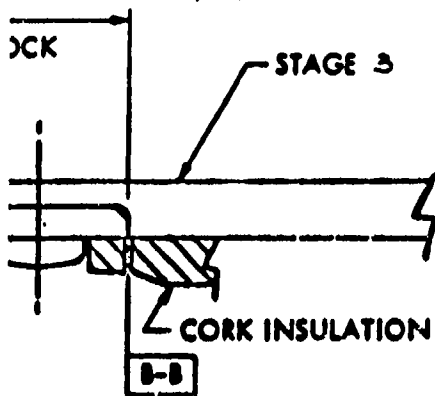
SECTION B-B
(SCALE 1/1)

← FWD →





SECTION A-A
(REAR VIEW REF)
(SCALE 1/10)



| <u>WEIGHT ESTIMATE</u> (LBS) | |
|------------------------------|------------|
| RING STRUCTURE | 5.3 |
| ORDNANCE & LOADING | 1.2 |
| SCREWS & NUTPLATES | 1.2 |
| RETAINER FITTING | 2.4 |
| 10% GROWTH ALLOWANCE | <u>1.0</u> |
| TOTAL WEIGHT | 11.1 |

CONFIGURATION 13

FIGURE 3.3-13: SHAPED CHARGE
ORDNANCE SEPARATION
SYSTEM

SHEET 5A

4. SMALL MISSILE JOINTS

To facilitate the task of the designer whose joint concept application is limited to the non-strategic missiles, this section is restricted to joint designs for missiles of 40 inch diameter or less.

Because so much of the total effort of missile design involves this size range, this section permits the designer to investigate joint concepts related by design loads, function and environmental considerations similar to his own requirements exclusive of the larger strategic vehicles.

A look in greater depth than usual, is taken at the joints used on AGM-69A, both because it represents current developments in the state-of-the-art and because it provides an overall picture of an approach to joint design as applied to a particular vehicle.

Supplementing the AGM-69A concepts, are representative joints used on other tactical and research missiles.

4.1 AN EXAMPLE DESIGN APPROACH (AGM-69A)

The AGM-69A was configured into four sections to facilitate manufacture, assembly and maintenance. These sections are the Payload, Guidance, Propulsion and Control sections (Reference Figure 4-1).

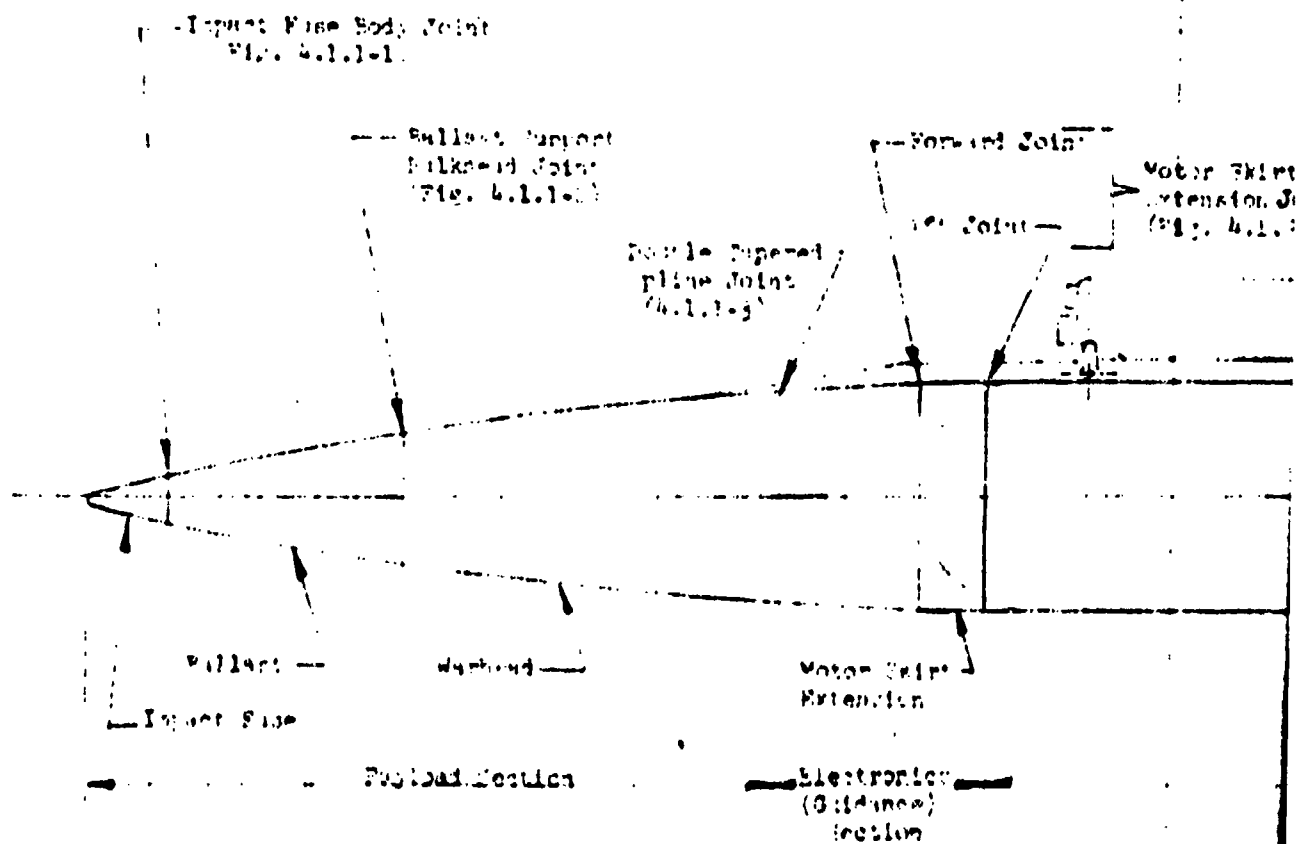
4.1.1 THE PAYLOAD SECTION

This section, of monocoque construction, is provided a circumferential ring at each of three separation joints. Its structural parts are:

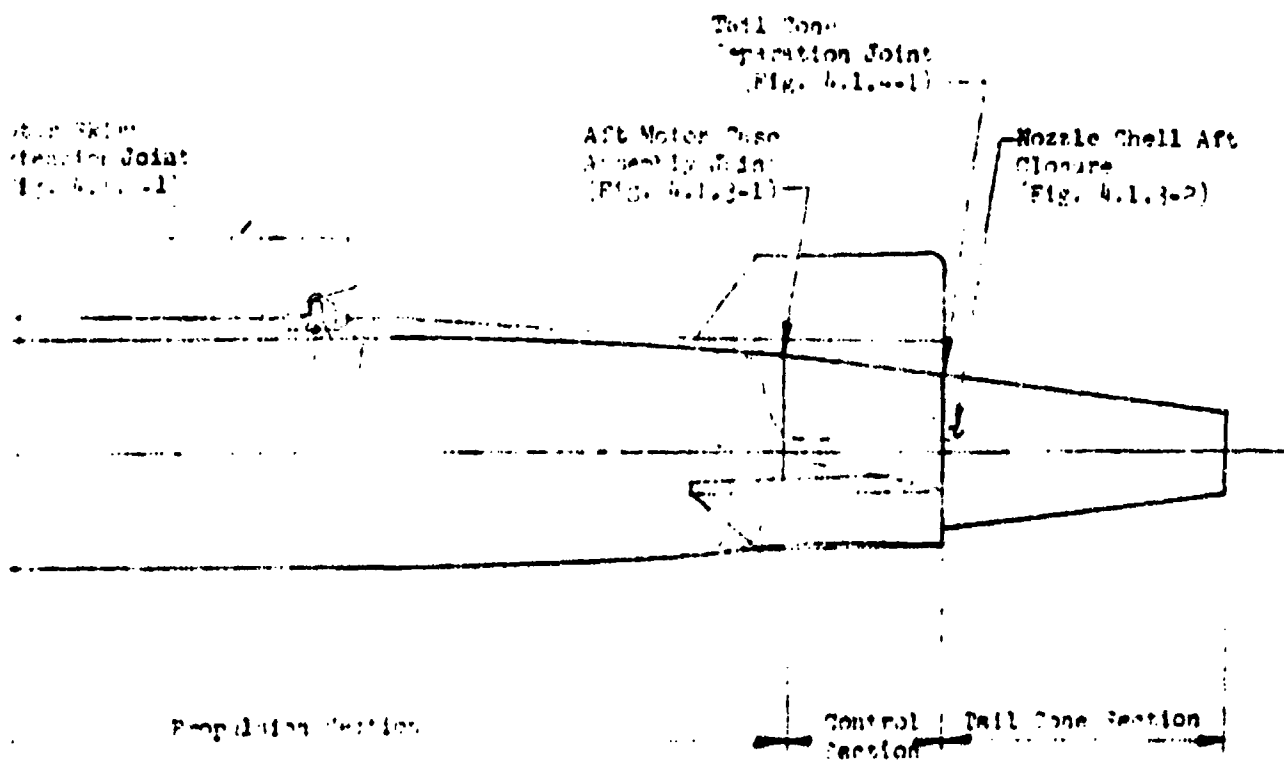
1. Impact Fuse Body
2. Forward Nose Shell
3. Warhead Section

4.1.1.1 IMPACT FUSE BODY JOINT (Figure 4.1.1-1)

The Impact Fuse Body interfaces with the Forward Nose Shell. The aft end of the fuse body has external interrupted threads to permit installation and removal from the Forward Nose Shell by rotating the impact fuse a quarter turn.



AGM-62A, SECTION A-C



SECTION AND JOINT LOCATIONS

FIGURE 4-1

SHEET 2

4.1.1.1 (Continued)

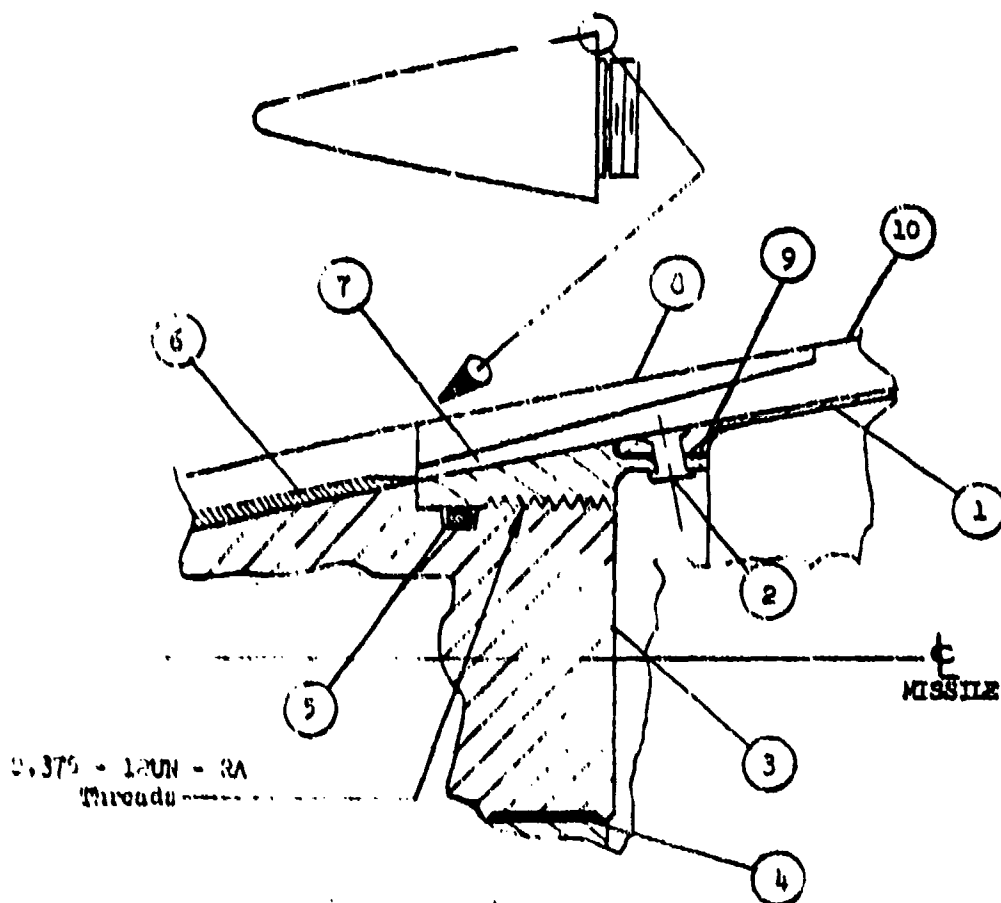
Riveted to the forward end of the Forward Nose Shell is a steel ring designed to accept the impact fuse interrupted threads. The ring is assembled to the shell using a sealant on the faying surfaces and fastened with monel rivets installed using a wet primer. A nylon insert is installed in a longitudinal groove in the steel ring for locking the impact fuse.

The joint is sealed by means of a synthetic rubber O-ring located in an annular groove provided at the base of the fuse body. Fuse body is torqued to 96 to 110 inch pounds.

USE FOR TYPEWRITTEN MATERIAL ONLY

SHEET 61

USE FOR DRAWING AND MANUFACTURING - NO TYPING MATERIAL



Scale: None

For Material Data See Table 4.1.1-1

IMPACT FUSE BODY JOINT

Reference: AGM-69A Program
DRAOM 20151-1, Para. 4.2.1

Figure 4.1.1-1

USE FOR TYPEWRITTEN MATERIAL ONLY

A. PART NAME/NUMBER

- ① Shell, Nose Section
(25A28299-101-11)
- ② Hexal Rivet (8 places)
- ③ Impact Fuse Body
(20A11411-130-11)
- ④ Front Nose Ring Insert
(26A13536-101-11)
- ⑤ "O" Ring
- ⑥ Radar Absorber
(25A24020)
- ⑦ Forward Nose Section Ring
(29A17189-101-11)
- ⑧ Collar, Thermal Nose Cap
(26A13566-101-11)
- ⑨ Sealant
- ⑩ External Insulation

2024-O Aluminum
CR-2-250/4
M.B. - 702

MS 20427 MS

2024-T4 Aluminum

General Purpose Nylon 6/6

Per L-P-410

MS 28775-140

Radar Absorber

STB 8-140



43304, MIL-S-8699
Normalized & Tempered
R.R. 033 MAF
H.T. 160-180 Ksi

Reinforced Phenolic Molding
RMS 8-72

MIL-S-8802 or RMS 5-44

93-078 Silicone Rubber
W/7% Quartz Micro Crystals
Dow-Corning Corp.

B. DESIGN CONSIDERATIONS - Critical load condition is terminal maneuver for
limit load

- a. Bending Stress = 
- b. Shear Stress = 

 Reference D2ACM20162-1, Sheet 5070

Table 4.1-1

SHEET 63

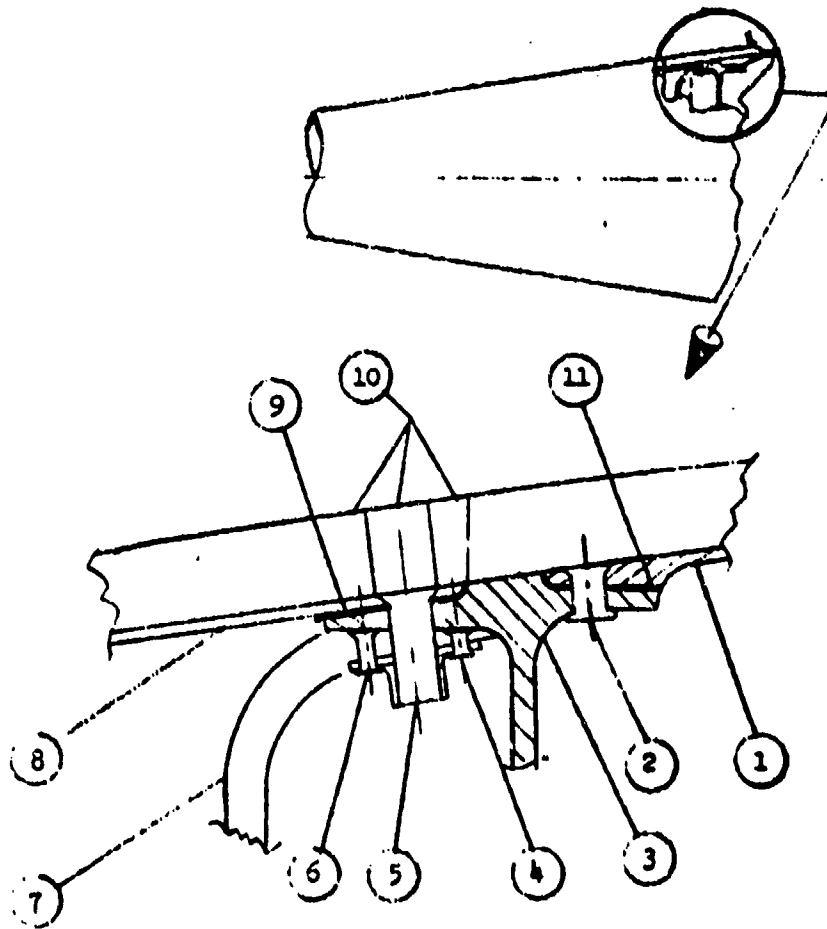
4.1.1.2 BALLAST SUPPORT BULKHEAD JOINT (Fig. 4.1.1-2)

To the inside of the forward flange of the circumferential Forward Warhead Ring is bolted the Ballast Support Bulkhead Ring. Three 1/4 inch diameter shear bolts are assembled through the ballast and warhead bulkhead flanges only, and fifteen are assembled through the nose section shell as well. Nut plates are riveted to the inside of the ballast support bulkhead ring to receive these bolts. About the outside surface of the aft flange of the Forward Warhead Ring, is riveted the Warhead Section Shell using 24 monel rivets. Access to the eighteen bolt fasteners is provided by a plug in the silicone insulation over the bolt heads.

USE FOR TYPEWRITTEN MATERIAL ONLY

SHEET 64

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL



Scale: None



For Design Considerations & Materials
Data see Table 4.1-2

BALLAST SUPPORT BULKHEAD JOINT

References: AGN-69A Program
D2 AGN20151-1, Para. 4.2.3

Figure 4.1.1-2

MATERIALS

| | | |
|---|---|--|
| ① | Shell, Warhead Section | 2024-O Aluminum QQ-A-250/4 H.T. -T62 |
| ② | Rivet (24 places) | MS 204-27M6 |
| ③ | Ring, Fwd Warhead Section, Station 34.70 (25A20546) | 7075-T73 Aluminum BMS 7-186 Class III |
| ④ | Rivet (2 places) | MS 20426D3 |
| ⑤ | 100° Reduced Head 1/4" Bolt & nut plate | BAC B30EL4 -6  & -5  |
| ⑥ | Rivet | MS 20426D3, 2017-T4 |
| ⑦ | Ring, Ballast Support Bulkhead | AISI 1026, Cold Rolled Annealed MIL-S-7952 |
| ⑧ | Shell, Nose Section (25A28399-101-11) | 2024-O Aluminum QQ-A-250/4 H.T. -T62 |
| ⑨ | Sealant | Eccobond 211 |
| ⑩ | External Insulation (P/N to be added) | 93-07B Silicone Rubber W/7% Quartz Micro Crystals Dow Corning Corp. |
| ⑪ | Sealant | MIL-S-2302 or BMS 5-44 |

B. Design Consideration - Nose Shell sized by missile ejection condition producing the following ultimate shell loads:

- 4,350 lbs transverse shear
- 52,500 inch pounds bending moment
- 140 in-lb torsion moment
- 40.6 psi max external pressure
- Design temp. 250° F.



 15 assembled through items ③, ⑦ & ⑧ above
 3 assembled through ③, & ⑦ above

Table 4.1-B

SHEET 66

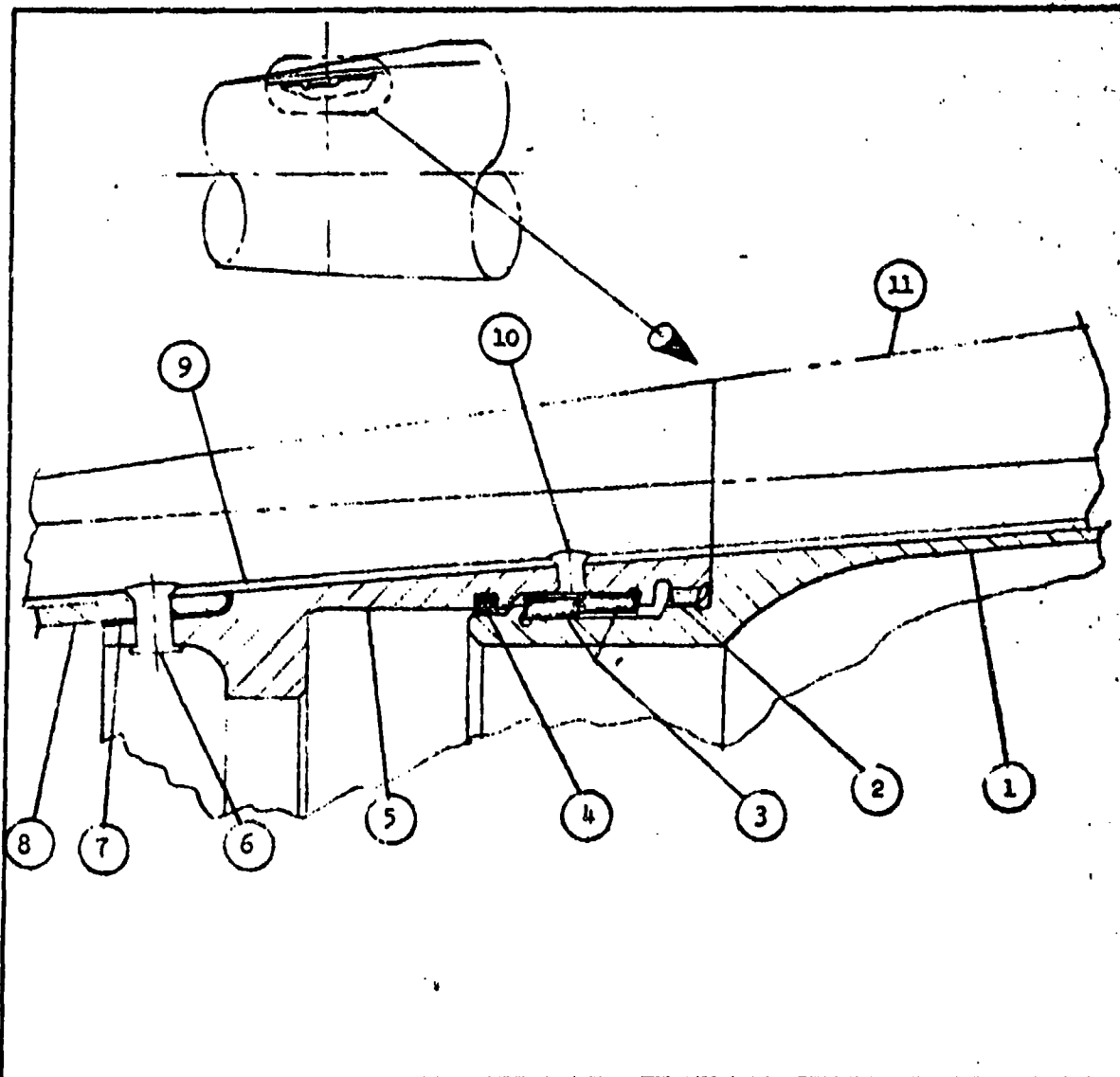
4.1.1.3 DOUBLE TAPERED SPLINE JOINT (FIG. 4.1.1-3)

This joint was designed to support the warhead and to mechanically interface with the missile at the forward end of the electronics section by means of a quick disconnect joint. The joint carries the loads associated with supporting the aft end of the warhead. In addition it satisfies the design considerations shown on Figure 4.1.1-3.

This joint configuration uses internal involute splines to transfer shear and torsion loads to matching external involute splines of the forward Electronics Section. Axial loads are transferred by removable circumferential tapered splines which seat themselves in an annular groove formed after the Payload Section is joined to the Electronics Section. These removable splines are installed through an aperture provided in the aft steel ring at clocking angle 45°. An arrangement is provided for indexing one spline and the other is driven into position using an axial force of 100 lbs. To prevent spline backup, a tang on the spline cover plate engages the transverse serration provided at the end of the spline. The spline access cover plate is bolted to the forward Electronics Section Ring by a single A-286 bolt. An O-Ring in the aft Warhead Section Ring forms an environmental seal after the Payload Section is combined with the Electronics Section.

USE FOR TYPEWRITTEN MATERIAL ONLY

USE FOR DRAWING AND HARDENING — NO TYPEWRITTEN MATERIAL



For Design and Materials Data
See Table 4.1-3

DOUBLE TAPERED SPLINE JOINT

Reference: AGM-69A Program
D2 AGM20148-1, Para. 4.2.1.2

Figure 4.1.1-3

A. PART NAME/NUMBER

- (1) Electronics Section Shell
- (2) Involute Splines (Part of 5)
- (3) Double Tapered Splines (2)
- (4) "O" Ring
- (5) Aft Warhead Section Ring
- (6) Monel Rivet (60 places)
- (7) Sealant
- (8) Shell, Warhead Section
- (9) Plate, Raceway Extension
- (10) Monel Rivet
- (11) External Insulation

Steel
4330 M, MIL-S-8802
H.T. 135-145 Ksi

Steel
4130 MIL-S-18729 Normalized
H.T. 135-145 Ksi

Silicone Rubber

Steel
4337 M, MIL-S-8699
H.T. 160-180 Ksi

MS 2042TM6

MIL-S-8802 or MS 5-44

Aluminum
2024-O, QQ-A-250/4
H.T. -T62

Aluminum
2024-T4, QQ-A-250/11

93-078 Silicone Rubber
W/7% Quartz Micro-crystals
Dow-Corning Corp.

B. DESIGN CONSIDERATIONS

- a. Transfer 270 K in-lb ultimate body bending load, 10 K lb ultimate transverse shear load, and 900 in-lb ultimate torsion load.
- b. Design temperature for (a.) is 250° F.
- c. Joint to have Payload Section interchange capability within 30 minutes while missile is in carrier rack.
- d. Minimized surface steps and gaps to satisfy radar cross section and aerodynamics requirements.
- e. Design must not compromise volumetric requirements imposed by warhead and electronics components.

Table 4.1-3

4.1.2 ELECTRONICS SECTION (Reference Figure 4.1.1-1)

This section is actually an assembly of two sections; the Electronics Shell forward and the Motor Skirt Extension aft. The structural joint components are identified as follows:

1. Electronic Section Shell with an integrally machined fitting at the forward end to accept payload sections by means of a quick disconnect joint.
2. Motor Skirt Extension
3. Raceway Fairing and Umbilical Cover

4.1.2.1 ELECTRONICS SECTION FORWARD JOINT (Figure 4.1.1-3)

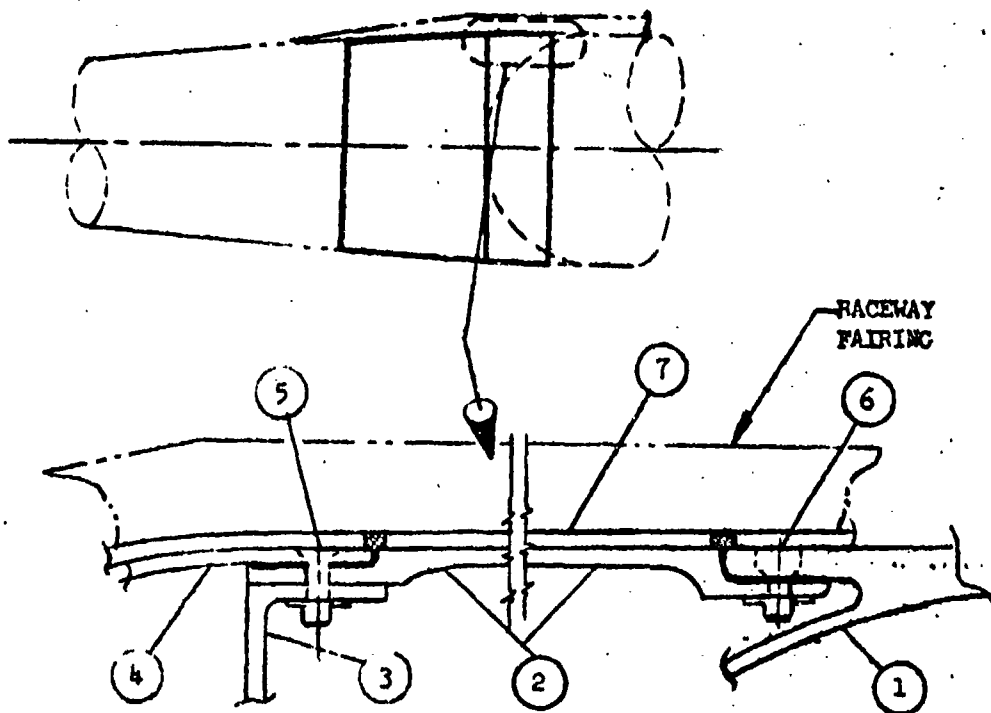
The internally machined ring at the forward end of the Electronics Section Shell is designed to mechanically interface with the Payload Section as part of the Double Tapered Spline Joint described in paragraph 4.1.1.3.

4.1.2.2 MOTOR SKIRT EXTENSION (Figure 4.1.2-1)

At the interface of the Electronics Shell forward and the Motor Skirt Extension is located the Electronic Support Fitting (See Item No. 3). This structural member provides a mounting surface for electronic equipment and is machined as an integral part of the environmental and umbilical systems. Its circumferential flange is fitted with nut plates to permit attachment of a conventional bolted spline joint. A similar joint less the support fitting provides the interface between the Motor Skirt Extension and the Propulsion Section.

USE FOR TYPEWRITTEN MATERIAL ONLY

USE FOR DRAWING AND HANDWRITING — NO TYPEWRITTEN MATERIAL



Scale: None

For Design Considerations & Materials Data see Table 4.1-4.

MOTOR SKIRT EXTENSION
FORE AND AFT ASSY JOINTS

Reference: AGM-69A
D2ACM 20148-1, Para. 4.2.1.3

Figure 4.1.2

A. PART NAME/NUMBER**MATERIAL**

| | |
|--|--|
| ① Motor Case, Fwd Dome & Skirt (20A14004) | Steel 4335V Air Melt Vacuum Degassed H.T. 205-225kps |
| ② Motor Skirt Extension (25A28087) | Steel 4330M MIL-S-8699 H.T. 160-180ksi |
| ③ Electronic Support Casting (25A28296) | Aluminum 356-T6 QQ-A-601 |
| ④ Electronics Section Shell (25A28613) | Steel 4330M MIL-S-8699 H.T. 160-180ksi |
| ⑤ 5/16 inch Bolts | BAC B30EL5-16 (2 places) BAC B30EL5-7 (27 places) |
| ⑥ 1/4 inch Bolts | NAS 1504-L (43 places) |
| ⑦ Umbilical Support Bracket (25A29260) | Steel 4340 AMS 6359 H.T. 160-180ksi |

B. DESIGN CONSIDERATION

Critical condition is missile ejection which produces:

1. Ultimate bending load of 375,000 in lb at 282° F. shell temp.
2. Ultimate transverse shear load of 10,000 lb at 282° F.
shell temp.

Table A.1-4

4.1.3 CONTROL SECTION

This section interfaces with the Propulsion Section forward and the Tail Cone Section aft.

4.1.3.1 AFT MOTOR CASE ASSEMBLY JOINT (FIG. 4.1.3-1)

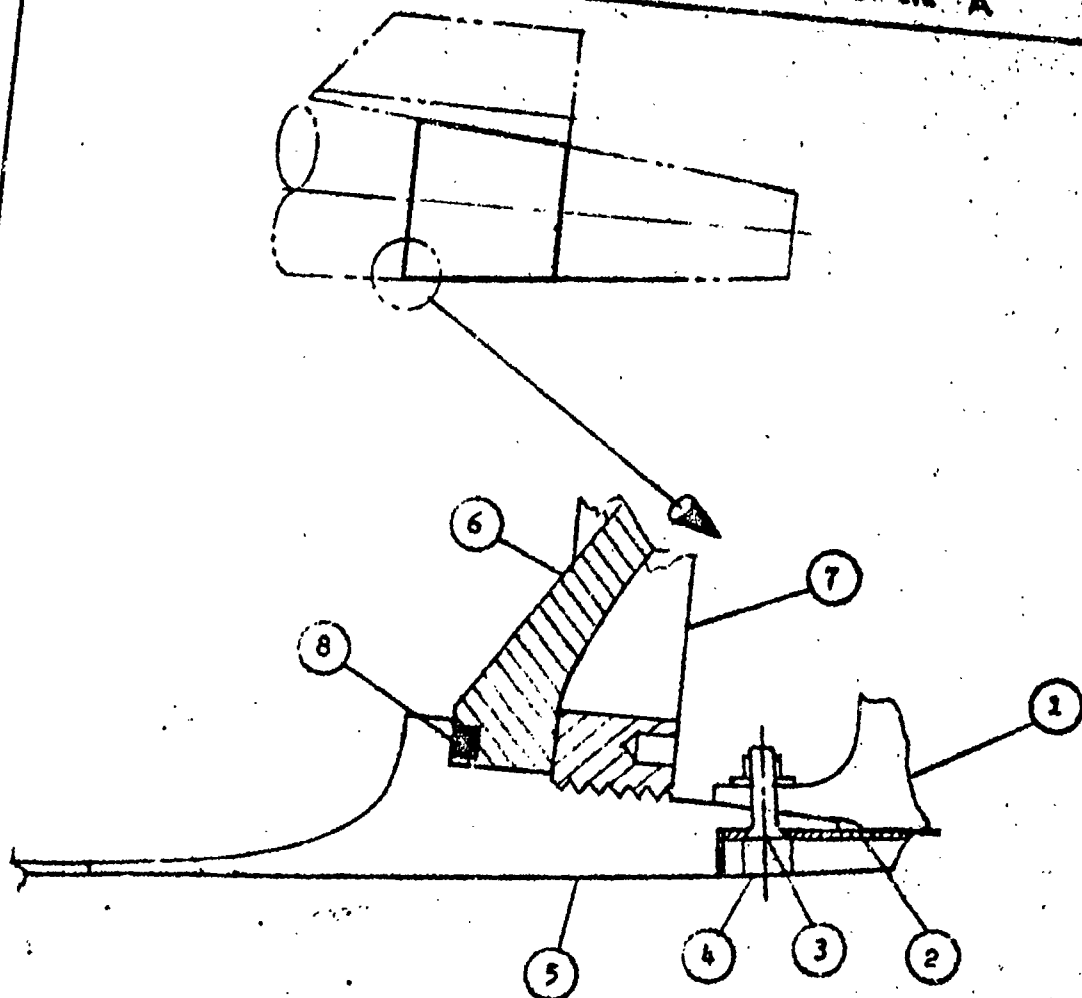
This joint provides the mechanical interface for attaching the Control Section to the Propulsion Section. It consists of a forged ring welded to the aft end of the motor casing. The Hydraulic Manifold is mounted on the inside of the forged ring aft flange and the Control Section Fairing is mounted on the outside of the same flange. In addition, the Nozzle Shell is mated to the Aft Motor Case Ring and mechanically held by a threaded retaining ring.

4.1.3.2 NOZZLE CLOSURE (FIG. 4.1.3-2)

A nozzle closure is included on the aft end of the nozzle shell which seals the motor to maintain the propellant in a controlled environment prior to motor firing. The closure is designed to rupture cleanly when the motor chamber pressure rises to 175+25 psi at first pulse ignition. The closure is bonded to the nozzle shell with an epoxy adhesive. The surface which forms the outer periphery of the nozzle closure forms an interface with the Control Section Fairing.

4.1.4 TAIL CONE SECTION

The single joint of the Tail Cone Section provides the mechanical interface with the Control Section.



Scale: None

For design considerations and materials data
See Table 4.1-5

AFT MOTOR CASE ASSEMBLY JOINT

Reference: AGM-69A
D2ADM20148-1, Para. 4.2.2.1

USE FOR DRAWING AND HANDPRINTING—NO TYPEWRITTEN MATERIAL

A. Part Name/Number**Material**

- ① Hydraulic Manifold Forging
- ② Fairing Shell, Control Section
(25A28080-110-11)
- ③ 1/4" Bolts
- ④ Silicone Insulation (Plug)
- ⑤ Motor Case Aft Ring
(20A14004)
- ⑥ Nozzle Shell
- ⑦ Motor Case Retaining Ring
- ⑧ "O" Ring Seal

Aluminum
6061-T6
QQ-A-367

Aluminum
6061-0
QQ-A-250/11
H.T. -T6

12 BAC30PB4-7
(thru ① ② & ③)

Steel
4335V, Air Melt
Vacuum Degassed
H.T. 205-225Ksi

Same as ⑤

Same as ⑤

B. Design Considerations

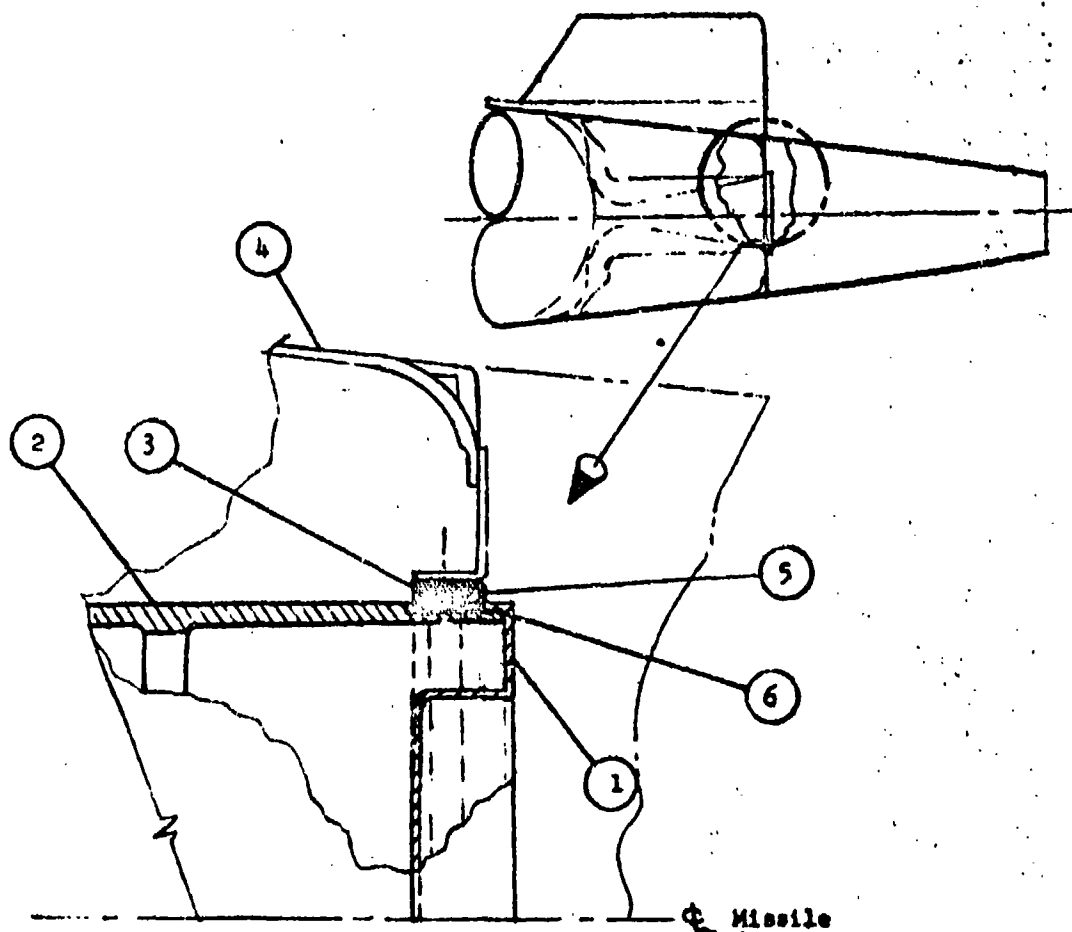
Ref. DRAWING 20162-1, Para. 5.3.8.2

TABLE 4.1-5

SHEET 75

USE FOR TYPEWRITTEN MATERIAL ONLY

USE FOR DRAWING AND HANDPRINTING—NO TYPEWRITTEN MATERIAL



Scale: None

For design considerations and materials Data
See Table 4.1-6

NOZZLE SHELL AFT CLOSURE

Reference: AGM-69A Program D2AGM20150-1

FIGURE 4.1.3-2

USE FOR TYPEWRITTEN MATERIAL ONLY

A. Parts:

1. Nozzle Closure
2. Aft Closure Shell
3. Engine Exhaust Seal
(MS413528)
4. Tail Cone Attach Fitting
(29A17132)
5. Seal Retainer Ring
(25AE8080-104-11)
6. Epoxy Adhesive

B. Design Considerations:

Ref. D2AG20162-1, Para. 5.3.8.3

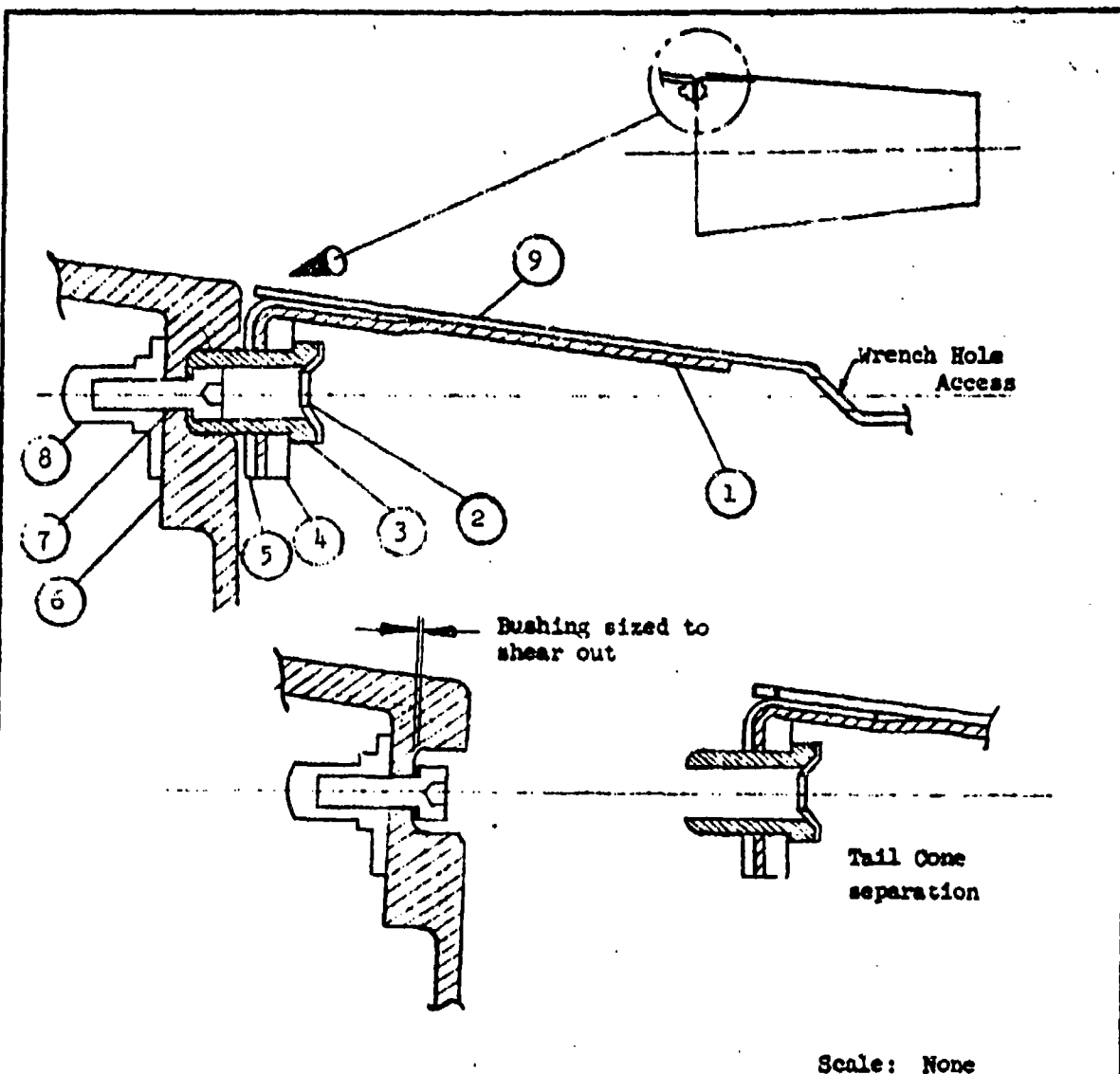
4.1.4.1 TAIL CONE SEPARATION JOINT (FIG. 4.1.4-1)

The Tail Cone is an aerodynamic fairing attached to the aft end of the ACM-60A missile to reduce drag force during external carry by the carrier aircraft. The tail cone remains attached to the missile until rocket motor ignition occurs during launch. Motor ignition causes pressure buildup within the Tail Cone shell, and at approximately 33 pounds per square inch (psi) internal pressure, the Tail Cone attachment bushings shear out, resulting in separation of the Tail Cone from the missile.

Through-drilled holes in each of three longitudinal depressions in the forward portion of the spin shell, provide access to Tail Cone fasteners at clocking angle 60, 120 and 300 degrees, for the assembly/disassembly function.

USE FOR TYPE SPECIFICATION MATERIAL ONLY

USE FOR DRAWING AND HANDWRITING — NO TYPEWRITTEN MATERIAL



For Design Considerations and Materials
Data See Table 4.1-7

TAIL CONE SEPARATION JOINT

Reference: AGM-69A
D2 AGM 20150-1, D2AGM 20148-1

Figure 4.1.4-1

A. PART NAME/NUMBER

- | | | |
|---|--|------------------------------------|
| 1 | Doubler, Tail Cone (25A258288-101-11) | 2024-0 QQ-A-250/5 H.T. -T6 |
| 2 | Retainer, Tail Cone (29A17190-101-11) | 6061-0 QQ-A-250/11 |
| 3 | Bushing, Tail Cone Attachment (29A17191-101-11) | 6061-T6 QQ-A-250/11 |
| 4 | Plate, Filler, Tail Cone (26A13529-101-11) | 6061-T6 QQ-A-250/11 H.T. -T6 |
| 5 | Ring, Tail Cone (25A28289-101-11) | 2024-0 QQ-A-250/4 H.T. -T6 |
| 6 | Tail Cone Attach Fitting (25A17132) | 2024-T6 QQ-A-250/4 |
| 7 | Attachment Screw (3 places) | MS 16998-28 |
| 8 | Nut Plate | BACMDOWN |
| 9 | Shell, Tail Cone (25A28291-101-11) | 6061-0 QQ-A-250/11 H.T. -T6 |

B. DESIGN CONSIDERATIONS:

Fairing to withstand local aerodynamic ultimate loads of 21.3 psi and

Tail Cone jettison ultimate load of 4130 lbs.

Table 4-1-7

4.2 SELECTED SMALL MISSILE JOINTS

Small missile joint applications which differ from approaches used for AGM-69A are presented in this section together with such design data as was available.

4.2.1 THE EXOS

A three stage sounding vehicle, the Exos started with the Honest John for its first stage. A ground-to-ground artillery rocket, Honest John yields very high thrust for over four seconds. The second stage used a Nike booster. Third stage was provided by a version of the Thiokol Recruit known as the Yardbird, which had an acceleration capability of approximately 80 g's.

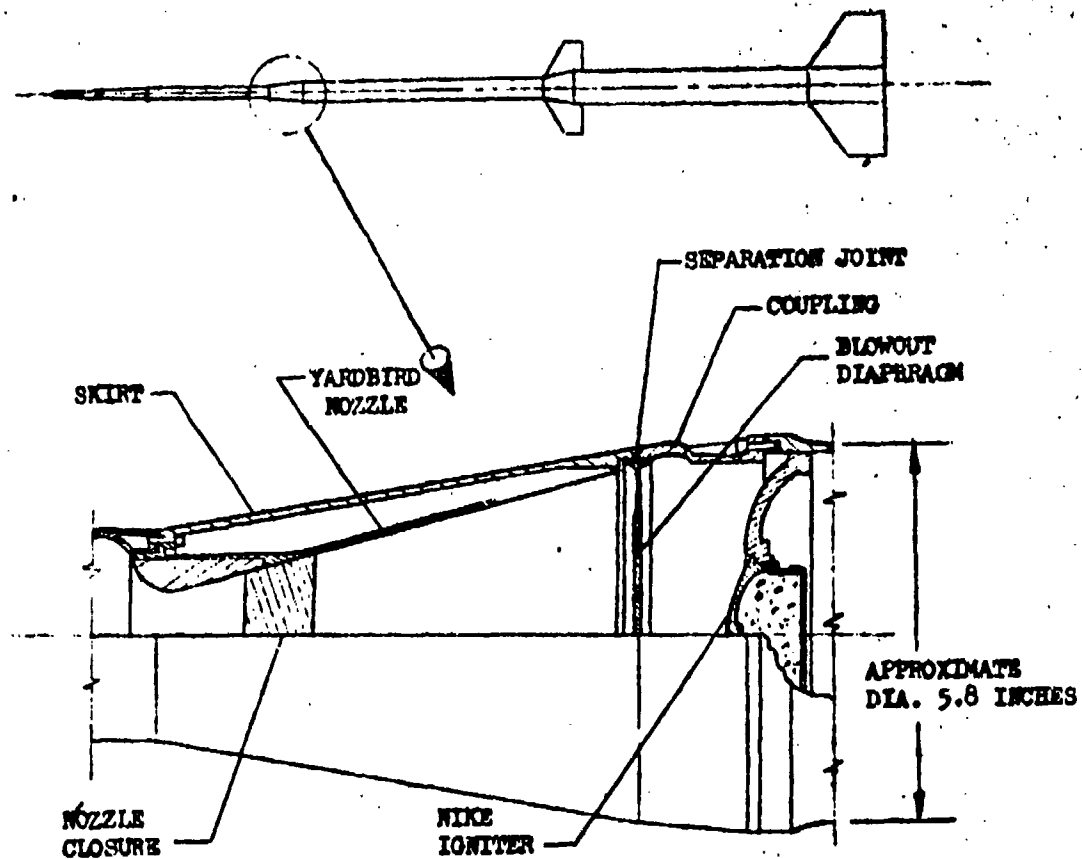
4.2.1.1 BLAST DIAPHRAGM SEPARATION JOINT (FIG. 4.2.1-1)

The joint used between the second and third stages serves both as an assembly and as a separation joint. The flared skirt on the forward stage and the coupling casting bolted to the aft stage are both threaded on the outside of the blast diaphragm. Upon forward (third) stage ignition, the pressure of the exiting gas bows the diaphragm so that the threads become disengaged from the flared skirt, and a clean rapid separation occurs.

This system is generally used between stages which are fired in succession without a coast period, to avoid large drag losses caused by the relatively large skirt diameter and the burned out preceding stage.

USE FOR TYPEWRITTEN MATERIAL ONLY

USE FOR TYPEWRITTEN MATERIAL ONLY



BLAST DIAPHRAGM SEPARATION JOINT

Scale: None

References: Expo Sounding Rocket, Small Sounding Rocket Symposium,
XIth International Astronautical Congress, Vol. II,
Stockholm, 1960

FIGURE 4.2.1-1

REV LTR B

US 4220-2000 REV. 1/66

BOEING NO.

82





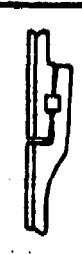

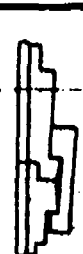


4.2 THE JOINT SELECTION PROCESS (SMALL MISSILES)





4.2.1 An example of the process which permits selection of a candidate joint for a particular application was the selection of the Double Tapered Spline Joint (Ref. Fig. 4.1.1-3) for the payload electronic section interface on AGM-69A.

4.2.2 An advanced study produced a series of candidate joint concepts, shown by Fig. 4.3-1. Each joint was compared against a weighted list of design considerations having a total numerical value of 10.0. Thus the numerical assessment indicated that the preliminary selection was Concept 9, the Spring Loaded Shear Key. However, in the evolution between concept and design, governed by more restrictive ground rules, new candidate designs were developed (Fig. 4.3-2) and a later selection was made, namely the "Tapered Spline Joint". The prime considerations for selection from this matrix were weight, cost, and evaluation for compatibility with missile system requirements.

Consequently, it can be seen that while the Bolted Joint had the lowest weight and cost figures, the missile system requirement for warhead interchangeability within carrier aircraft bomb bay, dictated the selection of the Tapered Spline Joint design.

USE FOR TYPEWRITTEN MATERIAL ONLY

| TYPE | ACTUATOR | OPERATES QUICKLY, EASILY, WITH FEW SPECIAL TOOLS | HAS RELIABLE SEAL | RE-USABLE MANY TIMES | EASY TO FABRICATE | LOW COST | USES LITTLE SPACE | LIGHT WEIGHT | LITTLE CHANCE OF INCORRECT OR INCOMPLETE INSTALLATION | TOTAL |
|---|--|--|-------------------|----------------------|-------------------|----------|-------------------|--------------|---|-------|
|  | MANUAL: 1. INSERT 2. ROTATE 1/8 TURN 3. LOCKING PIN | 2 | 1.0 | .3 | .2 | 2.0 | .5 | .5 | .5 | 10.0 |
|  | CLAMP SCREW, WRENCH TIGHTENED, SINGLE FASTENER | | .8 | .1 | .2 | 1.4 | .4 | .2 | .5 | 5.6 |
|  | WRENCH TIGHTENED FASTENERS (APPROX) | .5 | .5 | .2 | .1 | .8 | .4 | .2 | .4 | 5.6 |
|  | MANUAL: 1. INSERT 2. ROTATE 1/8 TURN 3. LOCKING PIN | 2 | .2 | .1 | .1 | 1.6 | .4 | .4 | .4 | 3.7 |
|  | MANUAL: 1. MATE 2. INSTALL SHEAR KEY 3. LOCK PIN | 1 | .8 | .1 | .1 | 1.0 | .5 | .4 | .5 | 5.3 |
|  | EXPANDING INTERNAL CLAMP, WRENCH OPERATED & LOCKED | 3.5 | .6 | .2 | .1 | .2 | 0 | .2 | .4 | 5.2 |
|  | ROTATING LOCK RING GEAR ACTUATED CAM-LOCK FACES | 2 | .7 | .1 | .1 | .4 | .5 | .1 | .3 | 4.2 |
|  | SPANNER OR STRAP WRENCH TURNS FLOATING RING | 2 | .5 | .1 | .1 | 1.0 | .3 | .1 | .4 | 4.5 |
|  | PLIES-TYPE OR C-CLAMP TYPE TOOL COMPRESSES KEY | 3.5 | .8 | .2 | .1 | 1.2 | .4 | .4 | .5 | 7.1 |

| ITEM | | | | | | |
|---|---|---------------------------|---|--|---|-----------------------------|
| COLUMN | ① | ② | ③ | ④ | ⑤ | ⑥ |
| STA 62.30 BODY JOINT (REF: CONFIG 29) | WEIGHT LB | COST | EASE OF OPERATION | WITHIN SPACE LIMITATION | COMPATIBILITY WITH AEC W/H | MFG COMPLEXITY |
| SNAP WIRE (D2AGM12209-5)  | 13.2 WT IS LOW BE- CAUSE NO ADDITIONAL SPACE IN GROOVE WAS PROVIDED FOR LOCK RING EXP | \$111.00 AVE COST 5 | 1. REMOVE COVER 2. EXPAND RING 3. SLIDE COMPT FWD UNTIL LOCK RING CLEARS GROOVE | NO LOAD REQMT CAUSES JOINT TO EXCEED SPACE AVAILABLE 1 | CURRENT W/H MTG TECHNIQUES OF AEC ARE NOT ADAPTABLE 2 | 4.44 M/H (FAB/COST ACCT) |
| COLLET (D2AGM12209-5)  | 19.8 | \$214.00 AVE COST 5 | 1. LOOSEN 3 SET SCREWS 2. ROTATE COLLET | NO LOAD REQMT CAUSES JOINT TO EXCEED SPACE AVAILABLE 1 | CURRENT W/H MTG TECHNIQUES ARE NOT ADAPTABLE 2 | 8.49 M/H (FAB/COST ACCT) |
| BOLTED  | 6.3 | \$85.00 AVE COST 5 | 1. REMOVE 26 BOLTS (10 MIN. OPERATION) | YES | AEC W/H MTG REQMT CAN BE IN- CORPORATED INTO THIS JOINT | 3.52 M/H (FAB/COST ACCT) |
| TAPERED SPLINE  | 10.1 | \$96.00 AVE COST 5 | 1. REMOVE COVER 2. UNLOCK SPLINES 3. REMOVE 3 SPLINES | YES | AEC W/H MTG REQMT CAN BE IN- CORPORATED INTO THIS JOINT | 2.02 M/H (FAB/COST ACCT) |

- 1 JOINT INTERFERES WITH CONFIG NO. 29 W/H
 2 AEC USES PLANGE MTG, RADIAL BOLTS, LARGE
THRD NUT OR INTEGRAL CASE - W/H
 3 MAX WIDTH OF CRACK DESIRED .001 WHEN
DEPTH EXCEEDS .10

- 4 MARGINS CANNOT BE REDUCED
MATH REQD FOR FAB
 5 EXCLUDES TOOL DESIGN ENGR
TOOL FAB COSTS & OPERATIONS
TO ALL JOINTS

CONSIDERATION

| ⑥ | ⑦ | ⑧ | ⑨ | ⑩ | ⑪ | ⑫ | ⑬ | ⑭ |
|-------------------------|---|--|---|------------------------------------|-------------------------------------|---|--|--|
| COMPLEXITY | EASE OF CORR CONT | RELIABILITY (FAILURE MODE) | REUSABLE | ACCESS TO JOINT FASTENER | SPECIAL TOOLS | INSTR RISK | SEALING SYSTEM | INSTR EFFECTS ON CORK |
| 4 M/H B/COST ACCT) | CAD PLATED CLOSE FIT & RELATIVE MOTION IN VIB & INSTR CAUSE GALLING & LOSS OF CORR PROTECTION | CENTERING SPRING FAILURE WOULD PERMIT LOCK RING TO UN-LOCK ON ONE SIDE | NO LIMITATION ON LOCK COVER SCREW REPLACEMENT | THRU ACCESS OPENING | RING EXPANSION TOOL REQD | RING FAILS TO ENGAGE | STATIC "O" RING W/RING ACCESS COVER | 1. ACCESS OPENING REQUIRES CORK PLUG COVER BOLT PLUG |
| 19 M/H B/COST ACCT) | HIGH INSTR TORQUE REQD CAUSES GALLING ON WEDGING SURFACES & LOSS OF CORR PROTECTION CAD PLATE | SET SCREW BECOMES LOOSE OR IN INADEQUATELY SET | SET SCREW COVER SCREW REPLACEMENT REQD BECAUSE OF CAD PLATE GALLING | EXPOSED AT ALL TIMES | LARGE STRAP TYPE TORQUE WRENCH REQD | FAIL TO TORQUE JOINTS OR SECURE SET SCREWS | STATIC "O" RING BUT CLEARANCE GAP REQD FOR COLLET ROTATION | 1. COLLET REQUIRES SEPARATE CORK INSULATION 2. SET SCREW PLUG (3) |
| 52 M/H B/COST ACCT) | FASTENERS INSTALLED WITH WET PRIMER. FAYING SURFACES IN RIVET JOINT ALSO WET PRIMED | BOLTS MAY BE CROSS THREADED | BOLTS REQUIRE REPLACEMENT BECAUSE OF FINISH GALLING | REMOVE 26 BOLT COVER PLUGS IN CORK | NONE | FAIL TO TORQUE BOLTS | STATIC "O" RING & WET PRIMER ON BOLTS | 26 HOLES IN CORK TO PLUG |
| 102 M/H B/COST ACCT) | CAD PLATED RING & AL ALODINED SPLINES STATIC JOINT NO MOVEMENT METAL TO METAL ZERO GAP ENGAGEMENT | NEGLECT LOCKWIRE OF SPLINES AFTER INSTR | NO LIMITATION ON SPLINE COVER SCREW REPLACEMENT BECAUSE OF FINISH GALLING | THRU ACCESS OPENING | SPLINE HANDLE REQD | INADEQUATE LOCKWIRE OF SELF-LOCKING SPLINES | STATIC "O" RING W/SPLINE ACCESS COVER | 1. ACCESS OPENING PLUG REQD 2. COVER BOLT PLUG |

NOT BE REDUCED BECAUSE OF MIN PAB

➡ "POSITIVE MARGIN" INDICATES JOINT EXCEEDS DESIGN REQUIREMENTS

DESIGN ENGR DESIGN & OPERATIONS COMMON

| (10) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) |
|--|---|--|--|---|--|--|-----------------------|---|
| HTL PECTS N CORK | NUMBER OF FAB PARTS | HARDWARE PARTS | JOINT COMPLEXITY | INTERCHANGE- ABILITY | DADAR CROSS SECTION | TYPE FAB TOOLS REQ'D | CAPITAL INVESTMENT | |
| ACCESS OPENING REQUIRES CORK PLUG OVER BOLT PLUG | 5-REGD 1-COVER 2-FTG 1-LOCK RING 1-CENTER- ING RING | 2-REGD 1-COVER SCREW 1-INDEX PIN | SIMPLE 3-MATCHED SURFACES 1-ANNULAR MATCH | SIMPLE LOCK RING GROOVE ALIGNMENT IS CRITICAL | GOOD 1-CRACK 3 | LATHE GRINDERS MILL ASSY 34 | \$405K | 1. POSITIVE MARGIN 2. CRACK 3. PER STRESS UNIT |
| COLLET BOURSES PARATE CORK INSULATION BT CROW LUG (3) | 3-REGD 2-FTG 1-COLLET | 4-REGD 3-SET SCREWS 1-INDEX PIN | MOST COM- PLICATED 48-MATCHED SURFACES DOUBLE CAM LUGS CLOSE TOLERANCES SET SCREWS | LUG ALIGNMENT CRITICAL | 2-CRACK 3 | LATHE GRINDERS MILL DRILL JIGS ASSY 20 | \$482.7K | 1. POSITIVE MARGIN 2. CRACK 3. PER STRESS UNIT |
| HOLES CORK PLUG | 2-REGD 1-DOUBLER 1-FILLER | 52-REGD 26-BOLTS 26-NUT PLATES | COMPLICATED 26-MATCHING BOLT HOLES ON TWO MATCHED OGIVES | 26 MATCHED RADIAL BOLT HOLES DRILL JIGS & GAGES REQD | 1-CRACK 26-RECESSED SCREWS 3 | LATHE MILL BROACH DRILL JIGS ASSY 80 | \$334.4K | NO STRESS CHECK BOLTS UNACCEPTABLE |
| ACCESS OPENING PLUG REQD COVER BOLT PLUG | 5-REGD 2-FTG 2-SPLINE 1-COVER | 2-REGD 1-INDEX PIN 1-COVER SCREW | SIMPLEST 3-MATCHED SURFACES 1-ANNULAR MATCH | SIMPLEST NO CRITICAL TOLERANCES PERPEN- DICULARITY OF MATING SURFACE TO 6 CRITICAL | BEST 2-GROOVES REQUIRE FILLING NO CRACK 3 | FORMING ROUTER DRILL JIGS ASSY 11 | \$561.7K | 1. POSITIVE MARGIN 2. CRACK 3. PER STRESS UNIT |

FIGURE 4.3-2

EDDY JOINT
TRADE STUDY
CHARSON 4/23/6

SHEET 85

3

4.4 AN ORIGINAL JOINT CONCEPT

This section presents a joint concept for a missile of 17 inches in diameter. Its primary purpose is to provide a means of load section to the main body of the missile. Its capability is intended to be the following:

I. Transfer:

- a. 270,000 in-lb. ultimate bending load.
- b. 10,000 lb. ultimate transverse shear load.
- c. 900 in-lb. ultimate torsion load.

II. Thirty minute assembly/disassembly of payload section while missile is attached to carrier aircraft.

III. Minimize surface gaps and steps to satisfy radar cross section and aerodynamic requirements.

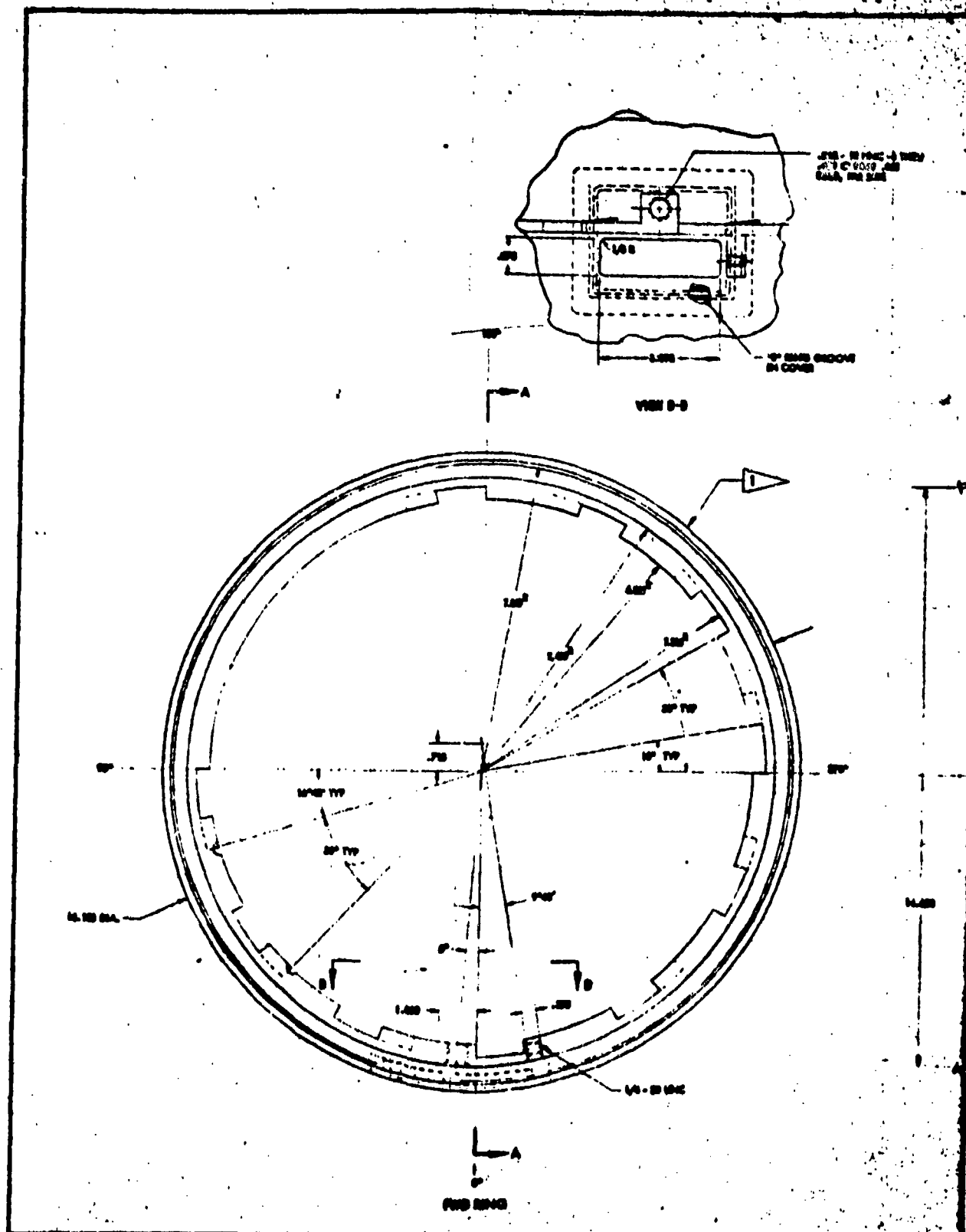
IV. Maximum possible internal volume for warhead and electronic equipment.

V. Satisfy I through IV at a design temperature of 270° F.

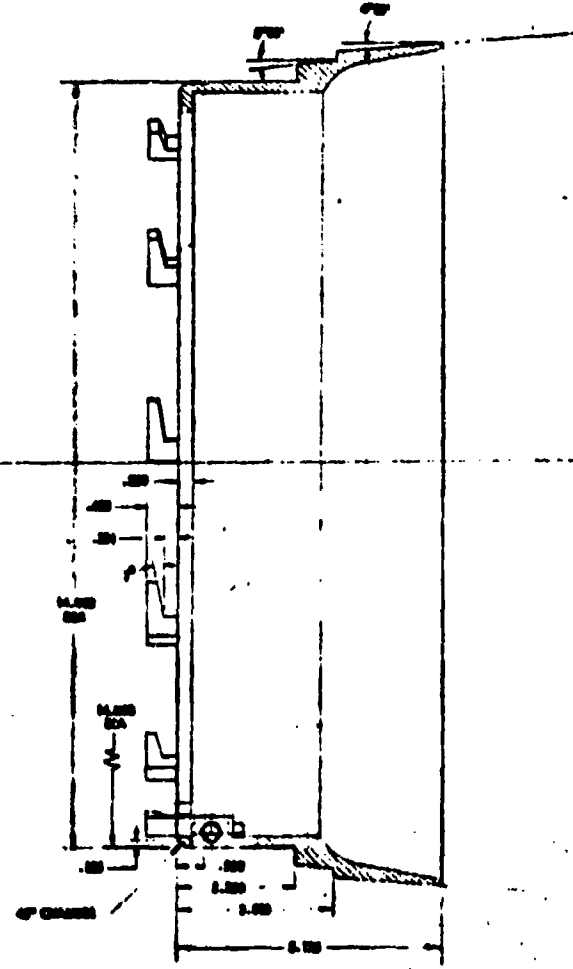
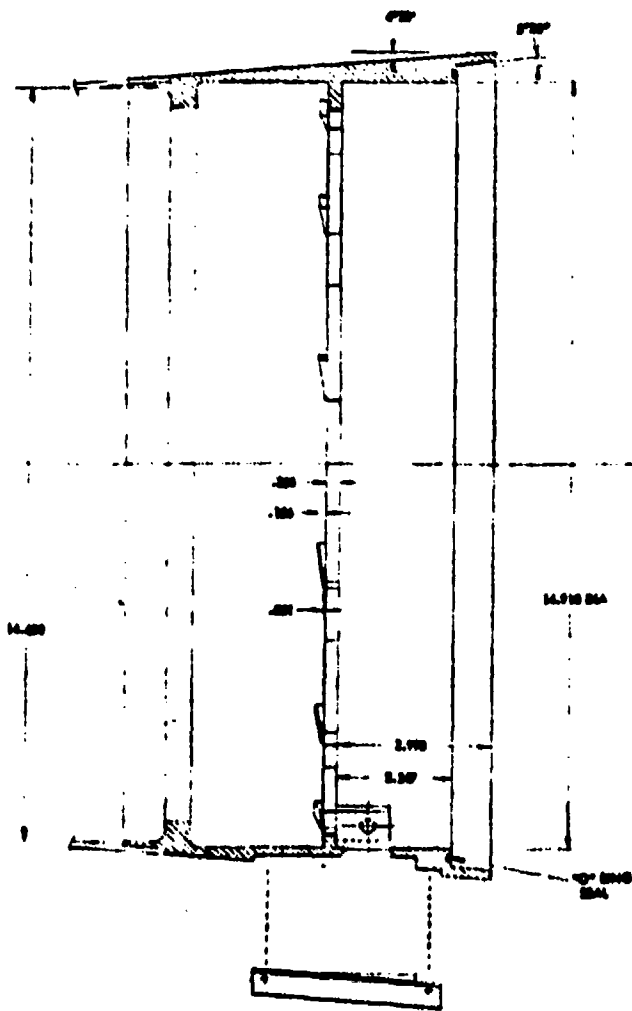
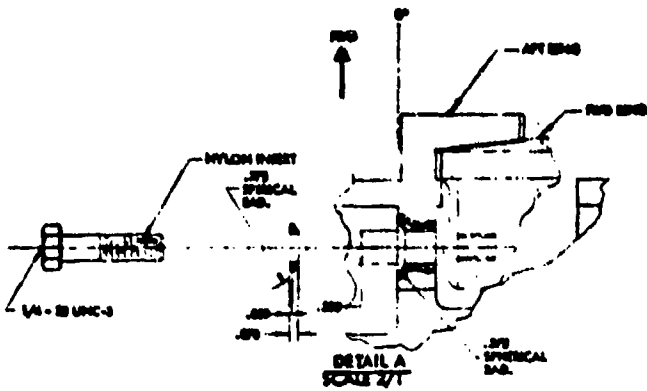
4.4.1 DESCRIPTION

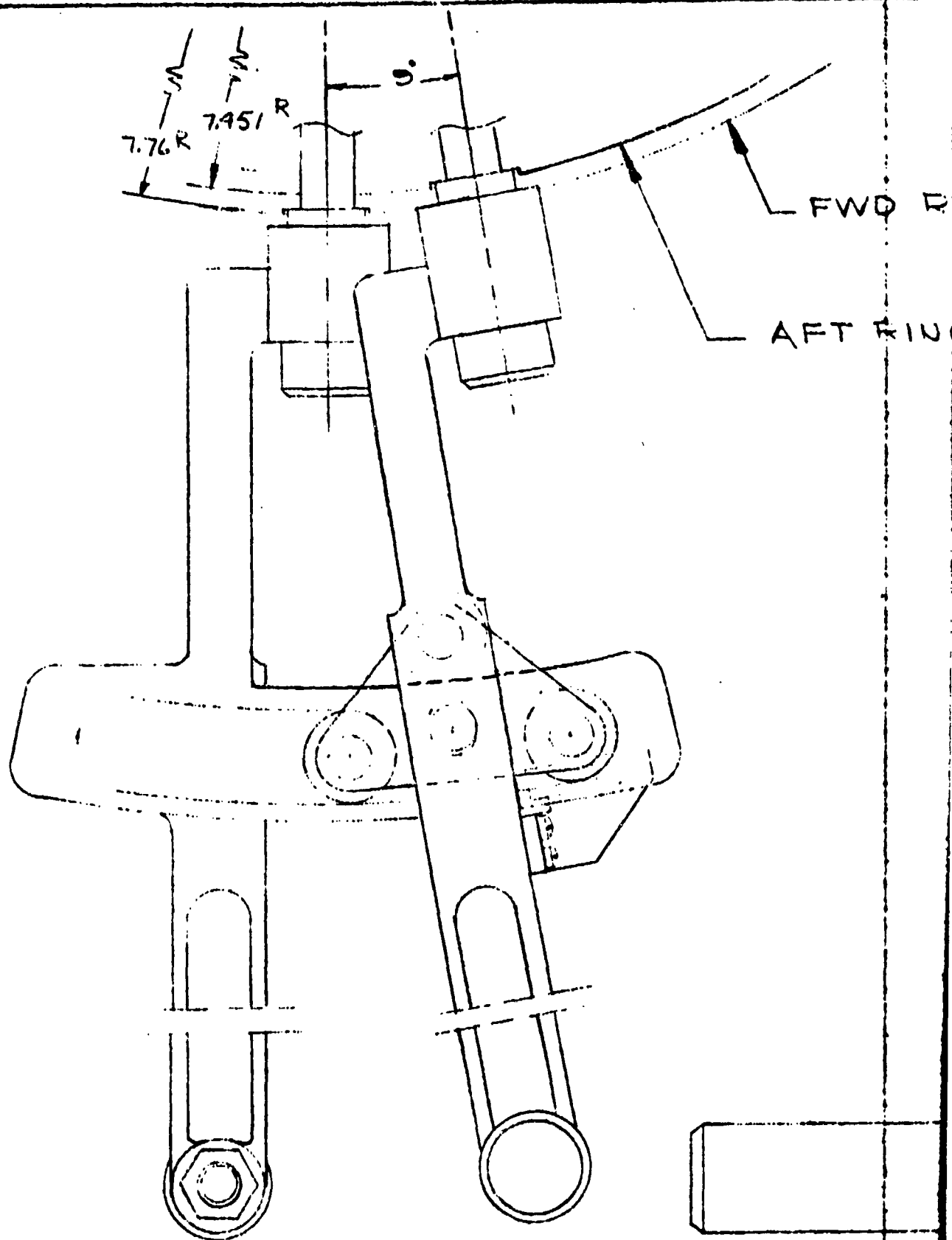
The joint consists of a forward ring attached by rivets to the nose section, and an aft ring similarly attached to the main body shell. The aft ring is assembled inside the forward ring so that twelve bayonets on the aft ring pass through twelve slots in the main flange of the forward ring. (Reference Figure 4.4.1-1). As viewed from the rear, the aft ring is rotated clockwise through approximately six degrees (6°). This draws the inclined bayonet surfaces of the aft ring flange against matching surfaces on the forward ring flange, while forcing the principal circumferential flanges of each to bear on one another. While thus held, the assembly is locked by installing a lock bolt through lugs, one on each ring, which have been drawn together by the rotation. Access is provided

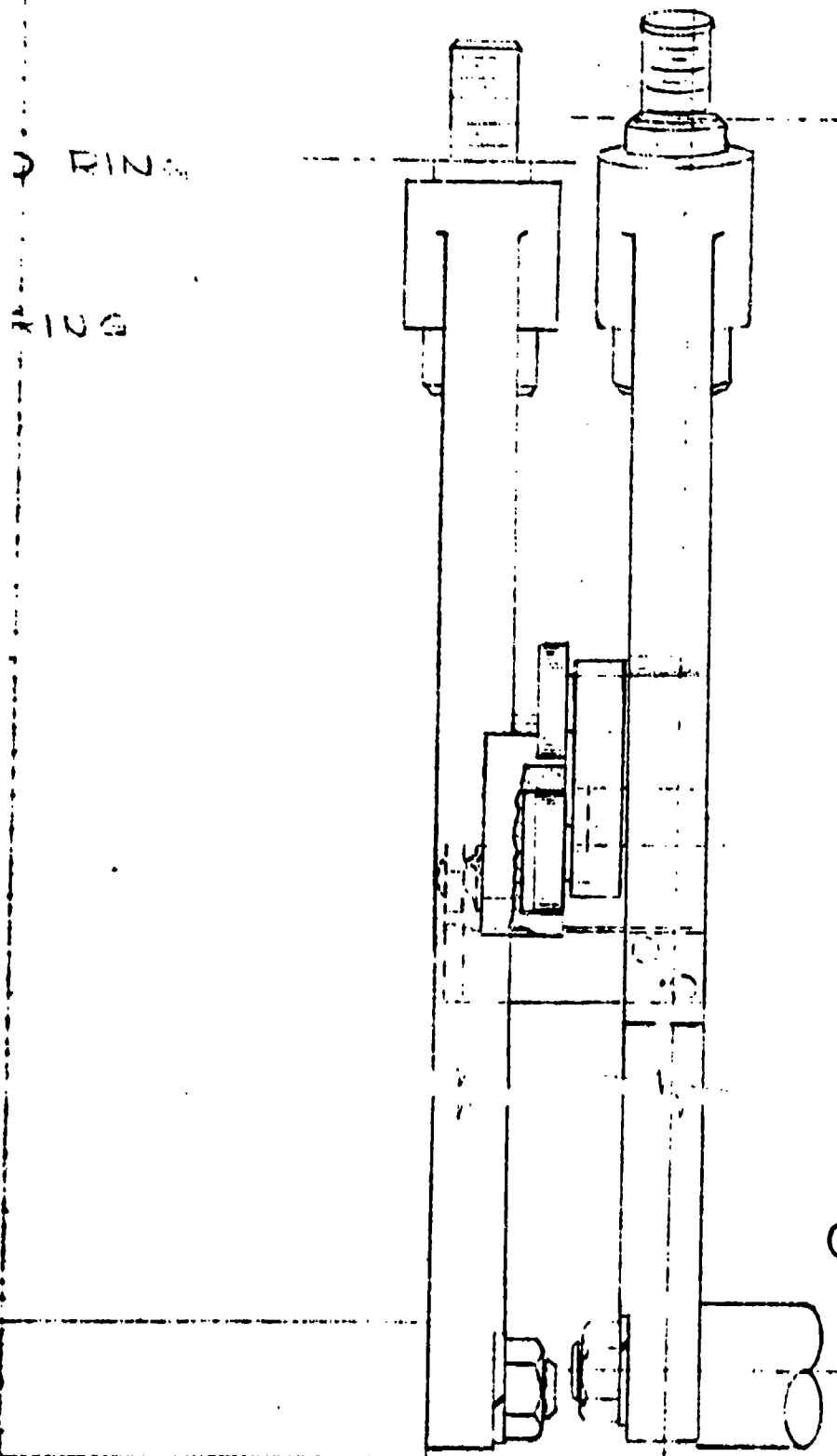
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CONCEPTUAL JOINT
ASSY/DISASSEMBLY
TOOL CONCEPT

FIGURE 4.4.1-2

4.4.1 (Cont'd)

by slots and holes in the respective rings which are then covered by a single plate which restores the external contour of the body shell. Threaded holes in each ring permit the assembly of a special tool (Reference Figure 4.4.1-2) required to assemble or disassemble the sections externally. The joint is fabricated from 4330 MOD steel, heat treated to 160,000 to 180,000 psi.

4.4.2 EVALUATION

The concept was submitted to Organization 2-5560 (Air Carried Missiles - Structures) for a preliminary evaluation, the results of which are provided on the following page.

USE FOR TYPEWRITTEN MATERIAL ONLY

COORDINATION SHEET

14-125711-1
REV. A

| | | | | |
|----|----------------|--------|-------|-------------------|
| TO | R. V. Ganhrell | 2-5166 | 1-51 | NO. 12-125711-1 |
| | W. R. Clark | 2-5166 | 62-26 | ITEM NO. |
| CC | W. H. Jacobway | 2-1630 | 62-26 | DATE July 2, 1960 |
| | T. F. Rona | 2-1755 | 60-62 | MODEL |

GROUP INDEX Air Carried Missiles - Structures

SUBJECT Structural Feasibility of Bayonet Missile Joint Concept

REFERENCE: (a) 2-5167-0-201 Missile Joint Concept Compendium of Missile Joints

In a preliminary qualitative structural evaluation of the missile joint concept of Ref. (a), the concept was found to be basically feasible from a structural point of view.

In the analysis of a typical missile joint application, the maximum stress in the joint was found to be in the order of 40% higher than the maximum stress in a normal cylindrical section of the missile. Also a missile with this joint compared to one without has approximately a 20% decrease in bending frequency.

A recommended change in the joint from a structural point of view is the elimination of all sharp corners to prevent local stress concentrations.

A more detailed stress analysis of this joint concept would depend on the specific configuration, weight distribution, and stiffness of the missile in which the joint is to be used. From this the mode shapes and frequencies could be found and, thus, the effect of the joint on dynamic loads, control interaction, and terminal guidance effectiveness could be determined.

Prepared by

R. C. Lundquist
R. C. Lundquist

Approved by

S. I. Gravits
for S. I. Gravits

5.0 DESIGN CONSIDERATIONS

There are many design requirements and considerations which must be kept in mind when selecting a joint design for missiles. These are usually unique for each application but usually fall into one or more of the following categories:

- (1) Ordnance Separation
- (2) Raceways
- (3) Sealing Joints

Each of these areas could be the subject of an entire document in itself. Consequently, no attempt will be made to tell a complete story. However, certain general information is useful for the design engineer to consider when making his selection and justifying its feasibility.

5.1 ORDNANCE SEPARATION

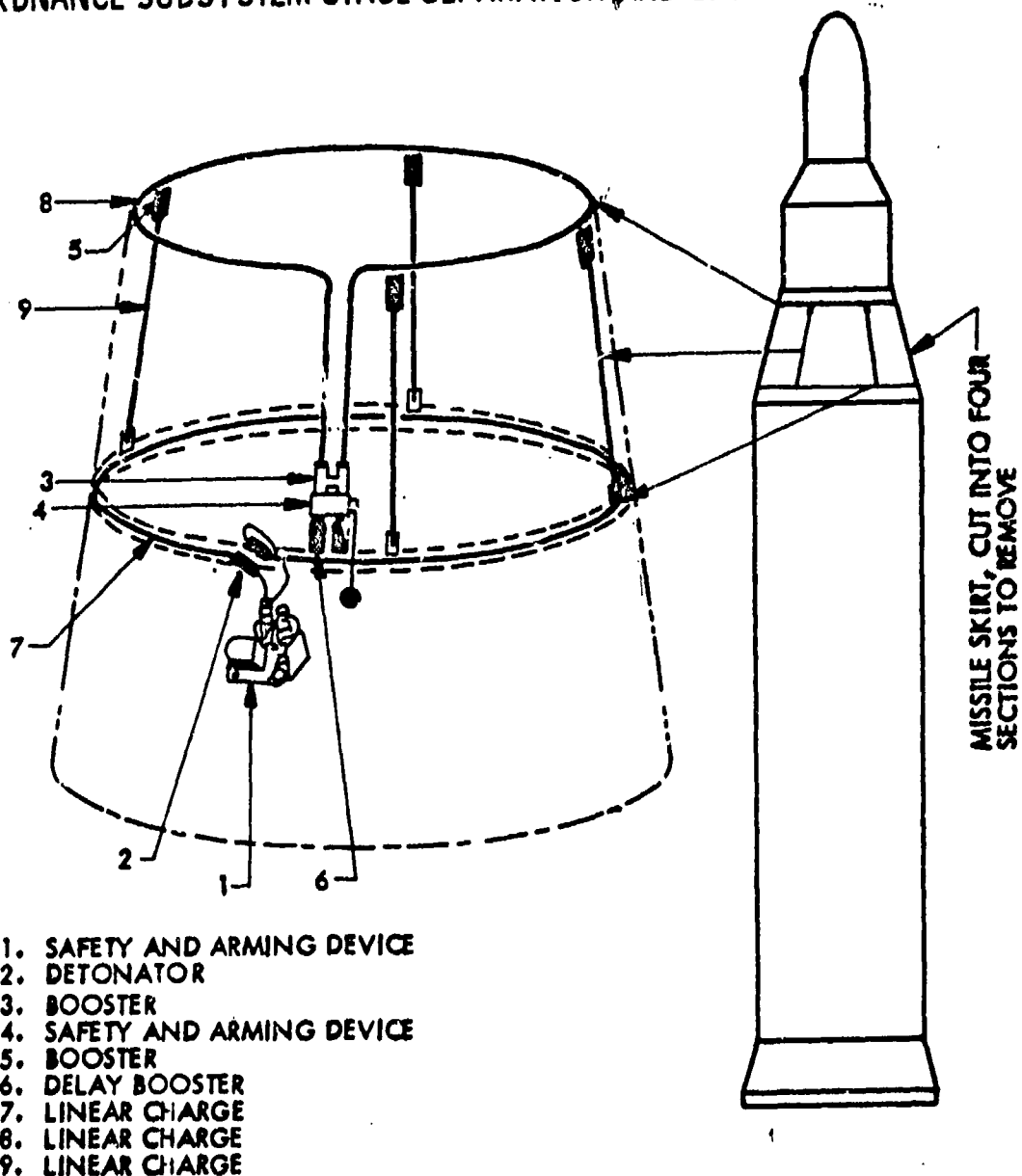
Information presented in this section is largely derived from the Boeing Research Document DR-24013-1, "Ordnance Components and Subsystems, Design Guide." This document should be referred to for additional details or expansion.

5.1.1 TYPICAL ORDNANCE TRAIN

Figure 5.1.1-1 shows, schematically, an ordnance train used for stage separation of an expended booster and removal of the upper stage booster skirt. (Refer also to Figure 3-1). This figure also identifies some of the ordnance components involved. They are discussed in Section 5.1.2 and pictorially shown on Figure 5.1.1-2.

ORDNANCE SUBSYSTEM STAGE SEPARATION AND SKIRT REMOVAL

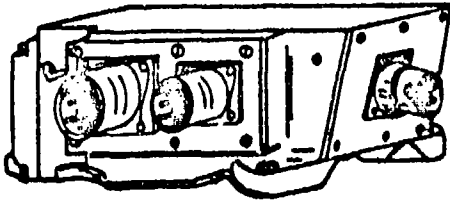
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NOTE: FOR COMPONENT IDENTIFICATION
SEE FIGURE 5.1.1-2

FIGURE: 5.1.1-1

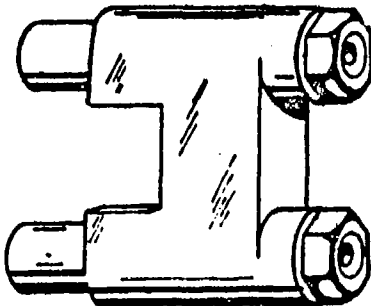
STAGE SEPARATION AND SKIRT REMOVAL COMPONENTS



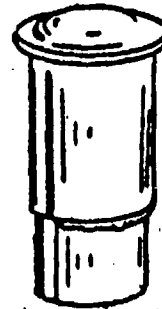
1. SAFETY & ARMING DEVICE



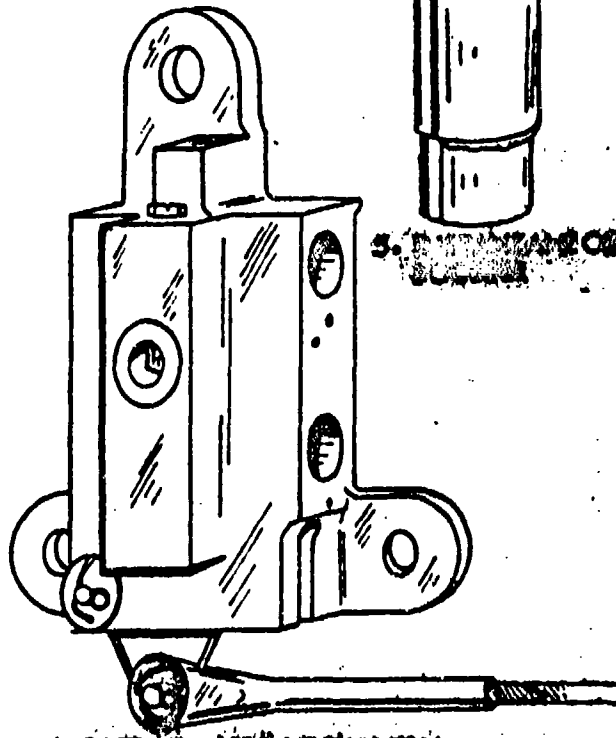
2. DETONATOR



3. H BOOSTER



5. DELAY BOOSTER



4. SAFE-ARM MECHANISM



6. DELAY BOOSTER



7, 8, 9. LINEAR CHARGE

FIGURE 1-1

USE FOR DRAWING AND HANDPRINTING — NO TYPEWRITTEN MATERIAL

5.1.1 Continued

This train is a unique configuration for one application and is not meant to be universal. It gives an idea of the influencing factors involved in an ordnance separation joint design.

The sequence of events which take place in this particular design is as follows:

- a. Electrical signal activates the Safe and Arm Device (1) which ignites the detonators (2).
- b. The detonators (2) explode and ignite the linear charge (7).
- c. The linear charge (7) explodes and separates the lower stage booster from the skirt.
- d. As the lower stage pulls away, it pulls the lanyard on the Safe and Arm Device (4), arming it.
- e. Safe and Arm device (4) ignites the delay boosters (6).
- f. After a delay period, the delay boosters (6) ignite the primary booster (3).
- g. Booster (3) explodes and ignites the linear charge (8).
- h. The linear charge (8) explodes thereby igniting the boosters (5).
- i. The boosters (5) ignite the charge (9) which explodes and breaks the skirt into four panels which are ejected by the force of the explosion.

5.1.2 TYPICAL ORDNANCE COMPONENTS

5.1.2.1 SAFETY AND ARMING DEVICE

5.1.2.1.1 DESCRIPTION

The Safety and Arming (S & A) device is a mechanism which controls the make and break of continuity of electrical firing circuits and the make and break of continuity of the explosive train of an ordnance subsystem. One variation of this description is for a similar device containing no explosive or pyrotechnic material. Such a device has been identified as Safe and Arm switch, Arm-Disarm Mechanism and Safety Switch, all performing the same function of make and break of electrical firing circuits.

5.1.2.1.2 APPLICATION

The S & A device is incorporated into an ordnance subsystem which, if advertently activated, would result in a catastrophic incident with possible loss of life and property.

5.1.2.2 EXPLOSIVE RELEASE MECHANISM

Explosive release mechanisms affect release of structural sections, panels, doors, pods, etc., by explosive or gas pressure failure of retaining hardware. The common release hardware used in explosive releases are explosive bolts, separation nuts (gas or explosive actuated), linear charge and linear shaped charge. The description of each type of release hardware, and common application of each type is noted below.

a. EXPLOSIVE BOLT

1. The explosive bolt is a special hollow bolt which is fractured by an internal explosive charge. The explosive charge is normally a high order detonation material either permanently loaded during manufacture or inserted later in the form of a cartridge. There are many different

3.1.3.2 Continued

configurations of explosive bolts, most of which have considerable blast and fragmentation when actuated. A few manufacturers do state that their explosive bolt will operate with no blast or fragmentation.

2. APPLICATION

Explosive bolts are used to release tension and shear loads. The application to release tasks requiring simultaneous actuation of more than four release points is not recommended because of reliability penalties.

Design for explosive bolt application should include evaluation of load ratings vs. weight and envelope of the bolt, weight and envelope of structure and for shock and blast effects of the particular bolt being considered. The design should also provide for installation of explosive cartridges after bolt installation is complete.

b. SEPARATION NUT**1. DESCRIPTION**

The separation nut is designed for installation in a manner similar to a regular nut in structural joining except that it will release the load when actuated by an explosive or gas generator charge. In the preferred configuration, the explosive or gas generated charge is contained in a separate component to be installed after the assembly operation is complete.

There are several configurations of release nuts ranging between the release of gas and fractured sections of the nut to those which release no gas or fractured sections when actuated. Each type will perform a satisfactory release.

5.1.2.2 Continued

2. APPLICATION

The release nut must be used only to release tension loads. Clearance holes for the mating bolts are required to allow bolt pull-out when the release nut is actuated. Shear loads must be controlled by shear pins or similar means.

Those release nuts actuated by high order detonation will, in most cases, release some explosive blast to the surrounding area but are relatively free from harmful fragmentation. In one application such a device has been enclosed in a light weight container and qualified for use in an explosive atmosphere. Release nuts actuated by gas pressure will release very little, if any, gas and will generate no shock.

Release nuts will normally be load rated in accordance with the load rating of the mating standard bolt.

Release nut application to release tasks which require simultaneous actuation of more than four points is not recommended because of reliability penalties.

c. LINEAR CHARGE

1. DESCRIPTION

Linear charges are relatively lightly loaded, continuous, explosive charges encased in metallic or plastic tubular containers. The linear charge is also known as Mild Detonating Fuse (MDF), Prima Cord, and Low Energy Detonating Cord (LEDC). The explosive specified for most installations is lead or aluminum encased RDX or PETN because of high reliability, low cost, temperature tolerance, safety and a high detonation velocity with resultant high energy shock wave release.

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5.1.2.2 Continued

2. APPLICATION

Linear explosive is used to rupture structural fittings for separation of missile sections and for propagation of detonation from one point to another in an explosive subsystem. RDX explosive has been qualified for use at altitudes above 200,000 feet in the Minuteman stage separation system. There has been no work done, however, to verify performance of any linear explosive after long exposure, (up to one year), to space environment. The application of explosives to any task, while exposed to cryogenic temperature, may cause extreme performance variation, see reference d.

d. LINEAR SHAPED CHARGE

1. DESCRIPTION

Linear shaped charges are similar to item c, Linear Charge, except that the cross section is shaped to focus a high energy stream in a predetermined direction to produce a cutting action. The linear shaped charge is also known as "Flexible Linear Shaped Charge (FLSC)".

2. APPLICATION

Linear shaped charge (FLSC) is used to cut a structural material for vehicle destruction and to separate sections from a vehicle. The explosive cutting performance is predictable for any of the common explosive loads except at cryogenic temperatures.

The installation of FLSC is most often accomplished during structural assembly because of the requirement for accurate location and orientation. The structure, with explosive installed, must then be considered an explosive component and will require special restrictions during storage and shipping.

5.1.2.3 BOOSTERS**DESCRIPTION**

The booster is an augmenting explosive or pyrotechnic component of moderate sensitivity, which is used in the explosive or pyrotechnic train to step-up the energy output of the primary material to initiate the comparatively insensitive main charge. The booster may be in the form of pressed pellets or in shaped containers as required by a particular system, see Figure 5.1.1-2 for additional example.

APPLICATION

Boosters will be applied to the initiation train of explosive components to step-up the detonation rate and energy release of the initiating or donor component to a level required to detonate the base charge or receiver component of an explosive train.

Boosters may also be applied to the initiation train of a gas generator or solid propellant motor to step-up the release of hot gases and burning particles into the main charge for more rapid build up of main charge gas pressure.

In both of the above systems, the booster may be incorporated only to reduce the total quantity of sensitive, primary explosive in the initiation components.

In the development of new explosive or gas generating systems, it is often possible to use an off-the-shelf booster in the initiating train. This must be done, however, with full cooperation of the booster manufacturer since an incorrect selection could compromise system performance.

5.1.2.4 INITIATORS

DESCRIPTION

An initiator is the first component activated in an ordnance train. It is activated by either electrical, gas pressure, or mechanical means to start the chain of events which results in ignition or detonation of the main charge. The term "initiator" is also used to identify some components in a seat ejection system which may not be the first units fired. However, the function is basically the same as noted above.

Initiators are identified by the following common names:

- a. Detonator - An initiator loaded with a high order detonation material to initiate detonation in an explosive charge.
- b. Squib - An initiator loaded with a flame and gas producing material to ignite deflagration type devices such as gas generators and rocket motor igniters. The term "squib" is also a common slang term used conversationally by some people to identify any initiating device or small pressure cartridge.
(This use creates some confusion.)
- c. Primer - Nomenclature used by some organizations for electrical or mechanical fired initiators which accomplish the same functions described in 1 and 2 above.

There are two basic types of electrically fired initiators, the conventional hot wire and the explosive bridge wire (EBW) types. The appearance and function of each type is quite similar. However, the control sub-systems differ considerably.

5.1.2.4 Continued

APPLICATION

An initiator is used to start every detonating or deflagrating function. It may be permanently assembled in the pyrotechnic or explosive train (such as a primer in a rifle cartridge) or preferably designed for installation after the remainder of the subsystem has been installed or assembled.

Every precaution should be taken to preclude the chance of a mixup between detonation and deflagrating type initiators in any installation. The two functions are not interchangeable and will probably result in a malfunction if improperly applied.

The application of initiators to systems that will be exposed to space environments for long periods prior to actuation, can only be accomplished with some risk, and verification of performance following such exposure may be required.

Electrically fired initiators are normally incorporated into a subsystem in such a manner that a duplicate capability is achieved which most often includes dual sources of power, dual switching, dual wiring, and dual bridgewires. The dual bridgewires may be incorporated as two bridgewires in one initiator or two, single bridgewire initiators. In the case of two single bridgewire initiators, either initiator must be capable of performing the complete function.

5.1.2.5 LIST OF REFERENCES

Document D2-24013-1, "Ordinance Components And Subsystems Design Guide", should be referred to when designing ordinance activated separation joint systems. In addition the following references are provided:

- a. D2-24052-1 Electro-Explosive Initiation Systems,
Design Guide Lines
- b. AFM 127-100 Explosive Safety Manual
(Air Force Manual)
- c. ORDP 20-270 Propellant Actuated Devices
(Library File No. US5 P 20-270)
- d. T5-6025 Test Report, Explosive Performance In
Extreme Cold (Saturn)
- e. MIL-1-23659 (U. S. NAVY - BU-WEAP) Initiators,
Electric, Design and Evaluation of
- f. AFETR 80-2 General Range Safety Plan
(Air Force Eastern Test Range Pamphlet)
- g. Machine Design, July 4, 1968, (pp 116 - 122) Designing
With Explosive Devices - Robert F. Reinking,
Project Engineering Supervisor, Aerospace
Components Div., Atlas Chemical Industries,
Inc., Valley Forge, Pa.

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5.2 JOINT TRADES EXERCISE

Frequently the designer is faced with the selection of a joint concept from a number of available alternatives. The use of a manufacturing approach to make the decision is demonstrated by the following example which uses case segmented joint concepts developed in the Minuteman Program.

5.2.1 MANUFACTURING CONSIDERATIONS

The six joints shown on Figure 5.2.1-1 have been evaluated on the basis of producibility in terms of fabrication time, field assembly time, and the relative importance of the two. Parts for each joint concept are interchangeable.

5.2.1.1 SUMMARY

Of the joint concepts considered, the taper pin and clevis joint have been selected as being the most desirable in terms of producibility. The joint requires more installation effort than some of the others. However, the findings indicated that initial fabrication time far outweighed field assembly time for the program concept of which this study was a part.

The primary advantage of the taper pin and clevis joint design concept is that it somewhat relieves the requirement for close hole alignment that most other designs require. This, of course, reduces part fabrication costs.

5.2.1.2 DESCRIPTION

5.2.1.2.1 STRAIGHT PIN JOINT (Concept No. 1)

Joint Concept No. 1, the clevis and straight shear pin, would require both the highest fabrication time and the highest assembly time of all the joints examined. The reasons for this are the extraordinary dimensional tolerances that would have to be maintained in making the rings, and

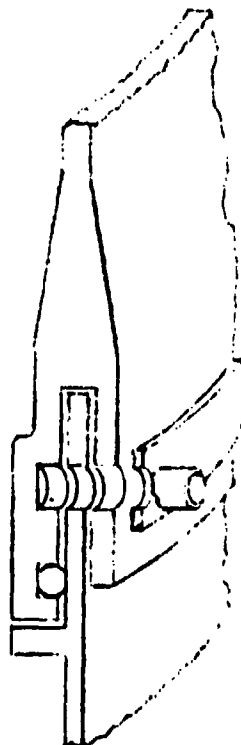
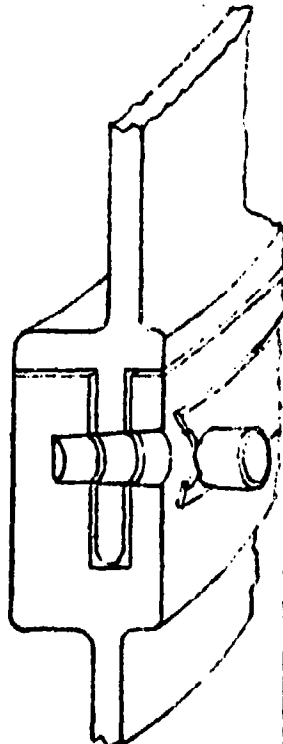
5.2.1.2.1 Continued

the level of alignment precision required in the joining operation. The joint is unlike the present Minuteman joint in that the fasteners carry the compression load. This requires that there be a close (Class I) fit between pin and matching holes. The joint is similar in concept to the type of shear joint used for Bomarc, but Bomarc had a 3 foot diameter whereas this design is for a 10 foot diameter. Of even greater significance is the method of assembly. Whereas Bomarc joints could be assembled only with the aid of elaborate holding fixtures and the most careful attention, this joint (No. 1 on Fig. 5.2.1-1) can be assembled with a minimum of mechanical aids and in a suspended mode.

To insure success of assembly, the dimensional accuracy of the related parts must be near perfect. Normal tolerances for master tool construction, hole coordination, axial alignment and closeness of fit between pin and holes must be abandoned in favor of super precision work. Increasing accuracy requirements from thousandths of an inch to tenthousandths of an inch would have a marked effect on fabrication costs.

5.2.1.2.2 TAPER PIN JOINT (Concept No. 2)

Although at first appearance this design concept appears to be about equal in complexity to the straight pin concept, in reality they represent opposite ends of the producibility spectrum in terms of fabrication costs. Although there remains some question as to whether or not the taper pin design here considered can be made interchangeable, it was assumed that a satisfactory design can be achieved. Such a design would provide for a positive fit, with no allowance, while at the same time the

| CASE SEGMENT IN | | | |
|---|---|--|----|
| BASIC JOINT TYPE | PIN AND | | |
| TO JOIN | STEEL CAS | | |
| JOINT VARIATIONS | STRAIGHT PIN U. T. C. | TAPERED PIN (With retaining ring) THICK & LOCKWELD | T. |
| |  |  | |
| CONCEPT No. | 1 | 2 | |
| <p>NOTE: The purpose of these early and preliminary joint arrangements is to provide examples for the trades exercise of this section. Their principal value as design concepts is probably that they illustrate features most to be avoided in joint design considerations. (See text.)</p> | | | |

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5.3.1.2.2 Continual

individual part tolerance could be relatively large. It is this less precise dimensional control that brings the cost of fabrication down, and the positive seating of one joint ring on the other (as on present Minute-man) that reduces the assembly time.

5.3.1.2.3 TAPER PIN, THREADED (CONCEPT NO. 3)

The threaded pin concept is more expensive to fabricate than the simple taper pin, because of the threads, taps and the need for a separate tapered insert. Threaded parts are, of course, more subject to damage than most other kinds of fasteners and the inserts would have to be replaced if the threads were to be damaged.

Assembly time for the threaded taper pin is greater than that for the simple tapered pin because a more precise alignment relationship must be achieved prior to pin insertion. On the other hand, disassembly should require less time because the pins can be extracted directly. The simple taper pins may have to be freed by a puller device. Finally, the effectiveness of a tapered threaded bolt, particularly in vibration, is highly questionable.

5.3.1.2.4 TAPER PIN, GLASS CASE (CONCEPT NO. 4)

There would be a slight increase in fabrication costs for this design over a similar joint type in a steel case. The difference would be due to a requirement for special drilling procedures using high speed, diamond impregnated cutting tools, and an expected higher frequency of part rejection. Assembly time should be identical with that required for the steel case application.

5.2.1.2.5 LOCKSTRIP JOINT, METAL CASE (CONCEPT NO. 5)

The lockstrip design is moderately more expensive to produce than the taper pin. Although, like the taper pin design, it can be produced using normal fabrication tolerances, it has more surfaces and more complicated surface relationships that necessitate the higher fabrication costs. Because of its self-aligning characteristics, it requires the least assembly time of all the designs considered. If the frequency of assembly and disassembly were to be relatively high, the lockstrip would be a good design choice.

5.2.1.2.6 LOCKSTRIP, GLASS CASE (CONCEPT NO. 6)

As can readily be seen from the drawings, the additional complexity associated with attaching metal rings to fiberglass case structure would substantially contribute to the cost of this design concept. The assembly time would, of course, be the same as that for the other lockstrip joint.

5.2.1.3 ANALYSIS

5.2.1.3.1 RELATIVE PRODUCTIBILITY (FIGURE 5.2.1-2)

The direct factory manhours associated with the actual fabrication of the various joint ring design concepts tend to vary over a rather wide range, from 340 manhours to 900 manhours. This is a ratio of 2.65 between the costs of the most expensive design and the least expensive. Tooling costs were not included because of the uncertainty of amortization factors, but if they had been considered, the spread would be even greater. The design concept considered to have the highest fabrication costs would also require the most expensive tooling. A more detailed explanation of these statements appears later.

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5.2.1.3.1 Continued

RELATIVE PRODUCIBILITY OF ENGINE CASE
SEGMENTING JOINT CONCEPTS

| Joint Type | Parts Fabrication Estimated Manhours | *Relative Producibility |
|---------------------------|---|----------------------------|
| 1. Straight Pin | 900 | 2.65 |
| 2. Taper Pin | 340 | 1.00 |
| 3. Taper Pin, Threaded | 500 | 1.47 |
| 4. Taper Pin (Glass Case) | 400 | 1.18 |
| 5. Lockstrip (Steel Case) | 380 | 1.12 |
| 6. Lockstrip (Glass Case) | 700 | 2.06 |

FIGURE 5.2.1-2

* Based on the establishment of 1.00 for baseline and assigning this value to the least expensive design

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5.2.1.3.2 RELATIVE ASSEMBLY EASE (FIGURE 5.2.1-3)

The manhours associated with assembly and disassembly functions, although much smaller in magnitude, vary over a range almost as great as that required for part fabrication. Here the ratio is 1 : 2.26 between the least and the most time consuming concepts. This could be of real significance if assembly and disassembly became a frequent occurrence, and in any case is important from the standpoint of possibly prolonging the field assembly operation.

RELATIVE ASSEMBLY EASE ASSOCIATED WITH ENGINE CASE SEGMENTING JOINT CONCEPTS

| Joint Type | Estimated Manhours | | *Relative Assembly Ease |
|---------------------------|--------------------|--------------|----------------------------|
| | Assembly | Dis-Assembly | |
| 1. Straight Pin | 7.5 | 7.0 | 2.26 |
| 2. Taper Pin | 4.0 | 6.0 | 1.56 |
| 3. Taper Pin Threaded | 6.7 | 4.7 | 1.78 |
| 4. Taper Pin (Glass Case) | 4.0 | 6.0 | 1.56 |
| 5. Lockstrip (Steel Case) | 3.0 | 3.4 | 1.00 |
| 6. Lockstrip (Glass Case) | 3.0 | 3.4 | 1.00 |

FIGURE 5.2.1-3

* Based on the establishment of 1.00 for baseline, and assigning this value to the design requiring the least assembly and disassembly time.

5.2.1.3.3 CONCLUSIONS

It can be seen from Figure 5.2.1-2 that the taper pin joint concept is the easiest to fabricate, and from Figure 5.2.1-3 that the lockstrip joint concept is the easiest to assemble. The lockstrip is somewhat more costly to fabricate than the taper pin concept, while the latter is about 1 1/2 times more time consuming to assemble.

5.2.1.3.3 (Continued)

There are no doubt several criteria by which the relative importance of these different manufacturing operations might be measured. In the absence of specific direction in this matter, however, cost was assumed to be the primary factor. On the basis of cost above, it would be necessary to perform the assembly and disassembly operation 12 times before installation costs would exceed initial fabrication costs. Since the operational concept being considered calls for only 8 removals per wing per year after initial emplacement, it would be about 10 years (the equivalent of the field life of the weapon system) before assembly costs associated with joint design equaled the initial cost of joint fabrication.

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5.3 SEALING JOINTS

When joints must act as efficient seals as well as structural members, certain general practices must be followed. The following is a "check list" which the engineer can use in his design development. It does not cover metal seals.

- (a) Sealing material should never "work" from the loads passing through the joint.
- (b) Shear loads carried by the joint should bypass the seal if possible.
- (c) The seal is subjected to the same thermal, chemical, and pressure environment as the rest of the joint. It must be designed for such.
- (d) Avoid thin, narrow gaskets. Their reliability is poor. Reliability is related to the pressure required to achieve a seal which is proportional to gasket area. Pressure is also proportional to the width to thickness ratio as shown in Figure 5.3-2. This figure shows the minimum sealing stress required for a cork and rubber gasket material. The curve is essentially the same for any material, the only difference being a vertical shift. Figure 5.3-1 indicates the relative differences between many materials.

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MINIMUM SEALING STRESS FOR REPRESENTATIVE NONMETALLIC GASKETS

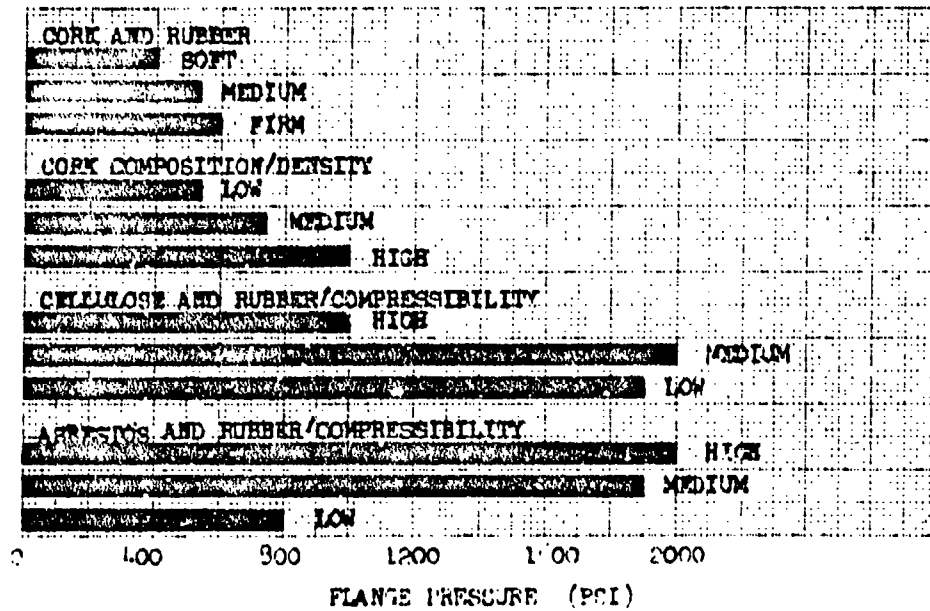


FIGURE 5:3-1

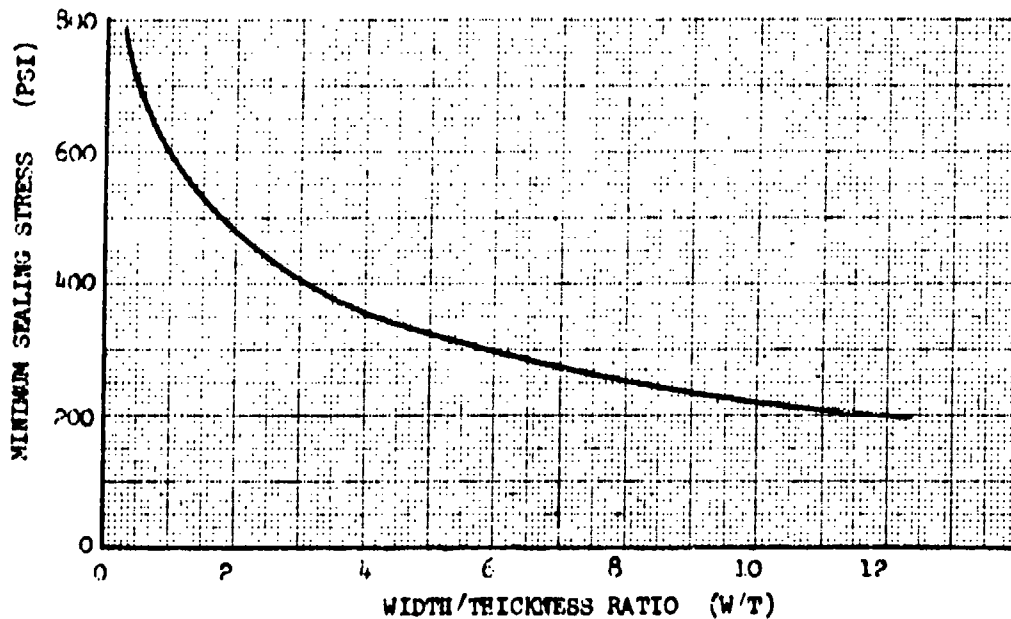


FIGURE 5:3-2

6.0 JOINT DESIGNS FOR LARGE, SEGMENTED, FILAMENT WOUND MOTOR CASES

Because their potential is so great, much emphasis is currently being placed on developing large segmented rocket motor cases. To realize weight and cost savings from the use of fiberglass in such applications, a lightweight reliable mechanical joint is required. However, the low bearing and shear strength of resin laminates force the engineer to develop unique joint designs encompassing metal to fiberglass or even fiberglass to fiberglass laminates, capable of developing the full strength of the basic fiberglass structure.

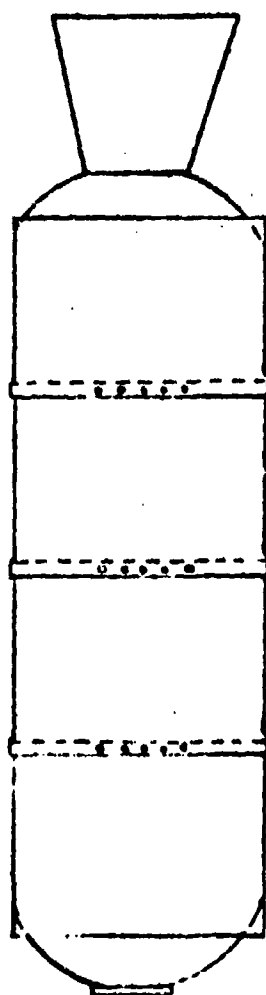
6.1 MOTORCASE CONCEPTS CONSIDERED

6.1.1 In this section, joint designs are considered for the two promising concepts for segmenting filament wound rocket motor cases illustrated in Figure 6.1.1-1. These are (a) the circumferentially segmented case (or segmented concept), and (b) the longitudinally segmented case (or modular concept). The segmented concept consists of a forward closure, aft closure, and cylindrical center segments connected by lightweight pinned joints. The modular concept is an assembly of several modules, composed of filaments oriented on meridional lines, that form portions of the forward and aft closures and are mechanically fastened to the forward and aft polar rings. The outer cylinder is of prefabricated hoop rings or circumferential windings.

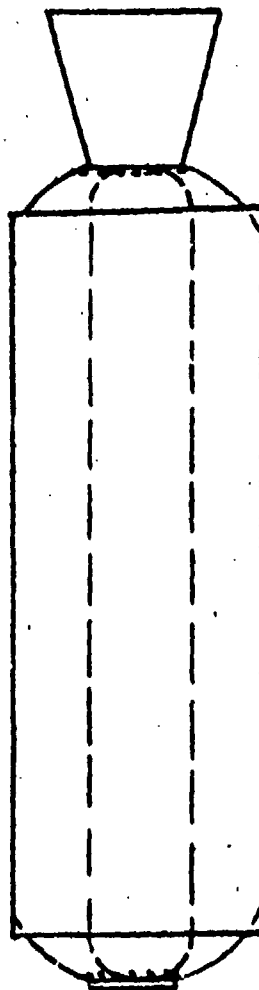
6.1.2 SEGMENTED CASE LIGHTWEIGHT JOINT

6.1.2.1 Since mechanically fastened joints are necessarily thicker than the case, they offer greater restraint to radial expansion than does the case. If the joints are reinforced with steel, the differential growth is further exaggerated by the contrast in elastic moduli (10.5×10^6 psi for glass vs 30×10^6 psi for steel). To minimize the contrast, use is made of the ability of the filaments to orient themselves. If the joint is located at the tangent point of the closure and the cylinder, the closure contour and its filament path can be readily adjusted to

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(a) Segmented Concept

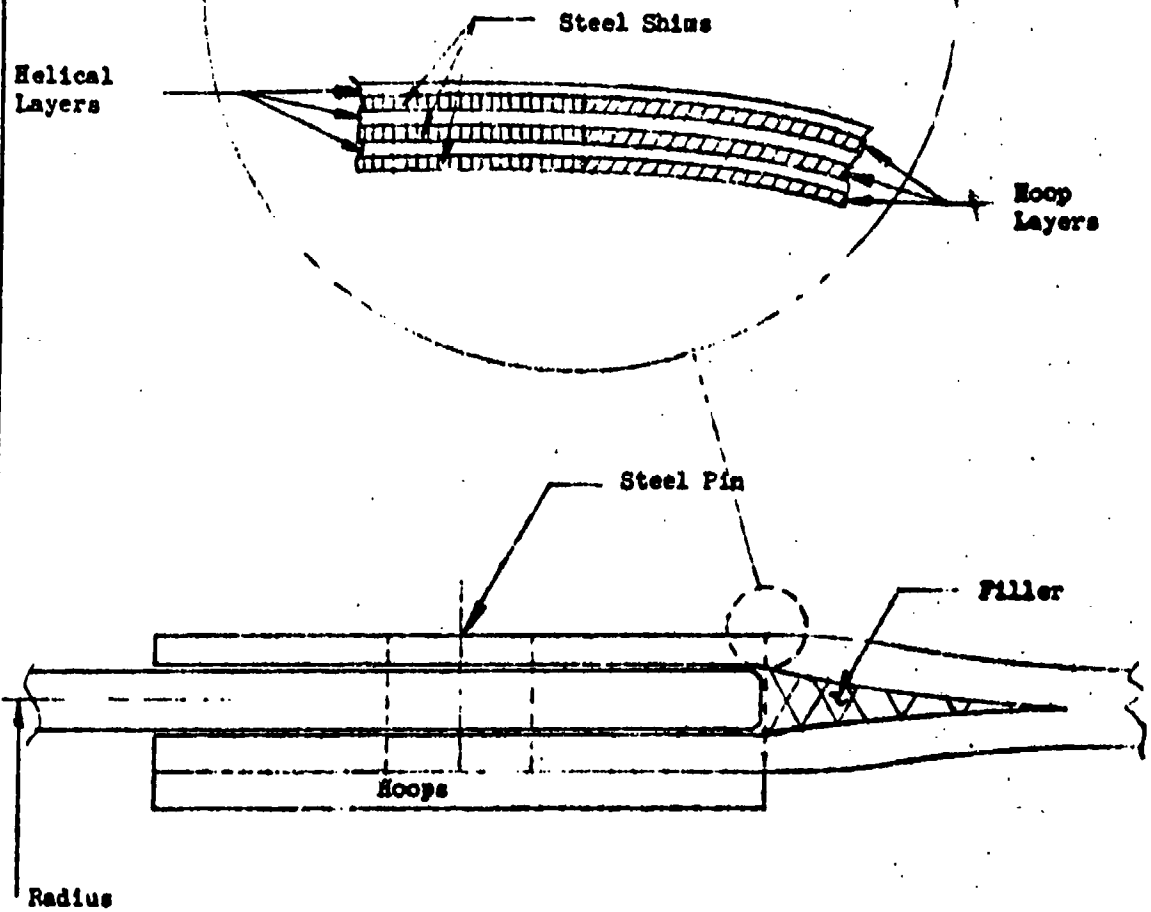


(b) Modular Concept

SEGMENTING CONCEPTS FOR FILAMENT WOUND ROCKET MOTOR CASES

FIGURE 6.1.1.1

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A CLEVIS JOINT FOR FILAMENT WOUND CASES

FIGURE 6.1.2-1

6.1.2.1 (Cont'd)

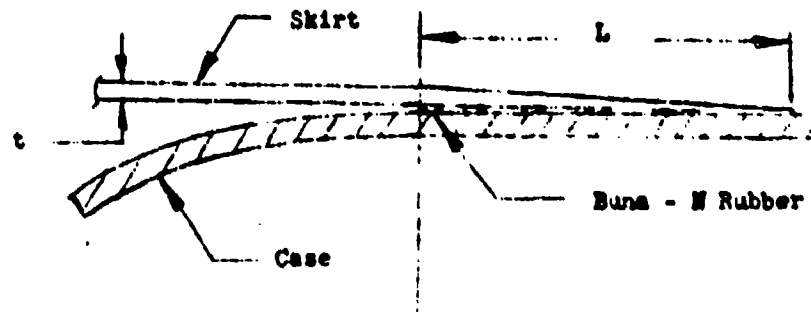
obtain the radial growth required to eliminate discontinuity stress. The joint growth can be made to coincide with the joint growth by using the critical angle principle; that is, as the wrapping angle exceeds $54 \frac{1}{4}$ degrees, the ratio of hoop strain to helical strain decreases.

Because rocket motor performance requirements for most applications, dictate joint locations and winding parameters, the joint concept is designed to provide the same radial restraint as the case. Trade studies indicated the clevis type joint of Figure 6.1.2-1 to be the most efficient concept. The clevis joint is composed of thin, high strength steel shims, laminated between the helical layers of the case with the hoop windings wound outside the joint region. It should be noted that the hoop and helical windings are interspersed in the case and that the hoop layers terminate at the start of the shims. The interspersing of hoop and helical windings requires an external skirt attachment. A design analysis of the joint is provided in the Reference (a.) document. (See 6.3).

6.1.2.2 SKIRT ATTACHMENT JOINT

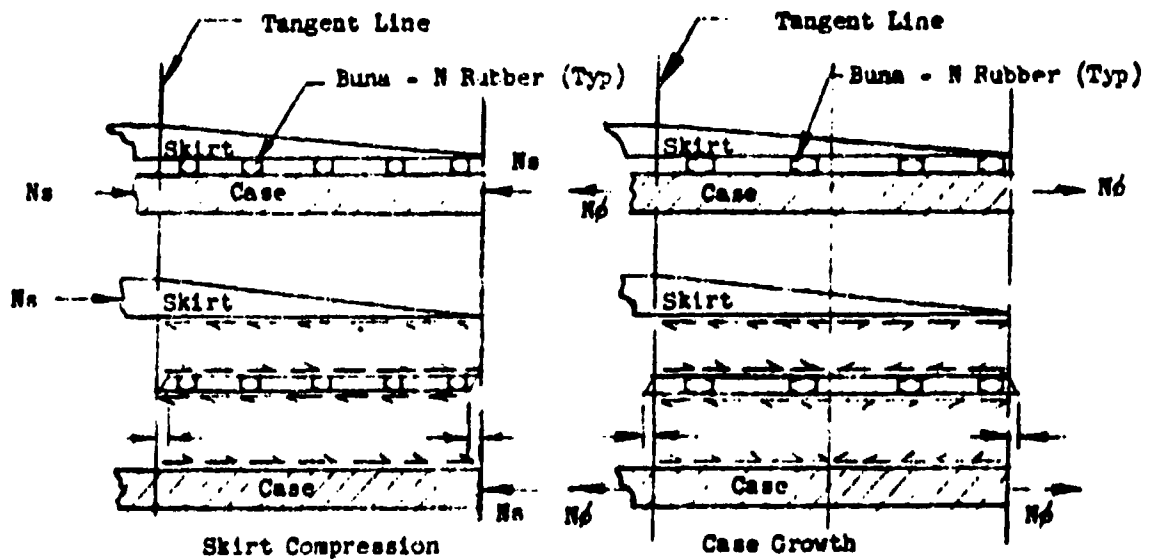
6.1.2.2.1 Experience has indicated that under the influence of high longitudinal strain in the case and compressive strain in the skirt, a pure resin bond between skirt and case is unsatisfactory, or at best unreliable. To circumvent this problem, a concept was developed which uses a layer of elastomeric material between skirt and case to reduce shear stresses and improve reliability. This joint is shown schematically in Figure 6.1.2-2. A free body representation of the effect of both Skirt Compression and Case Growth on the joint is shown on Figure 6.1.2-3. An analysis of such a joint together with a discussion of its fabrication problems is included in Reference (a.).

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ELASTOMERIC SKIRT ATTACHMENT

FIGURE 6.1.2-2



SHEAR STRESS IN AN ELASTIC BOND

N_s = Longitudinal Force, Compression

N_b = Longitudinal Force, Tension

FIGURE 6.1.2-3

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6.1.3 MODULAR MOTOR CASE CONCEPT

6.1.3.1 The two basic elements of the modular concept are the module and the hoop ring. The modules are preformed and precured with all fibers oriented in the longitudinal direction, extending beyond the tangent lines to form either or both domes. The domes described by the modules consist of only longitudinal fibers, hence, their contours must describe a "no hoop load dome" which is discussed in greater detail in the "Dome Analysis" section of Reference (a.) . The circumferential strength of the cylindrical section is supplied by hoop rings which are fitted over the assembled modules. These hoop rings also consist of precured and preformed unidirectional fibers.

6.1.3.1.1 MODULE JOINT (TYPE A)

The tension load in the module is transferred into steel foil which is integrally wrapped with the module. The foil in turn carries the load into a bolted joint connecting the adapter ring (Reference Figure 6.1.3-1). The analysis is basically similar to that presented for the segmented joint referenced in 6.1.2-1.

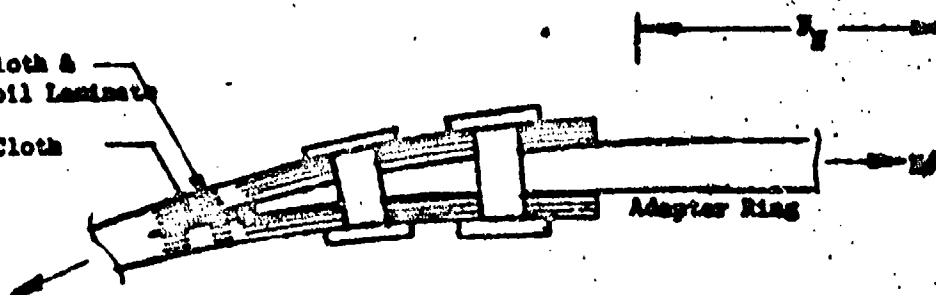
6.1.3.1.2 MODULE JOINT (TYPE B)

This light weight clevis joint provides a unique design which eliminates bending and assures strain compatibility at the polar ring equal to that carried by the outer plate. (reference Figure 6.1.3-2).

6.1.3.1.3 FABRICATION PROBLEMS

Steel sheets designed to carry bearing loads in the joint areas are laminated between the glass. Any necessary reinforcement or filler cloths are added in conjunction with the steel laminates. When loading permits, the skirts are wrapped as an integral part of a hoop ring instead of using the elastomeric bond discussed in 6.1.2.2.1 (Reference Figure 6.1.3-3). The following requirements demand extreme care in laminating the steel with the module:

Glass Cloth &
Steel Foil Laminates
Filler Cloth



H_p = Longitudinal Force, Tension

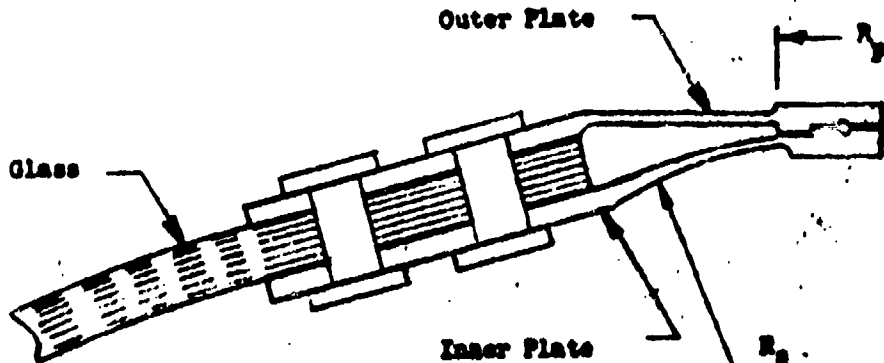
R_p = Any Radius

MODULE JOINT (TYPE A)

Center of Dome

FIGURE 6.1.3-1

Outer Plate
Filler Glass



R_p = Radius to Center of Dome

R_s = Radius Coordinate to Polar Shell

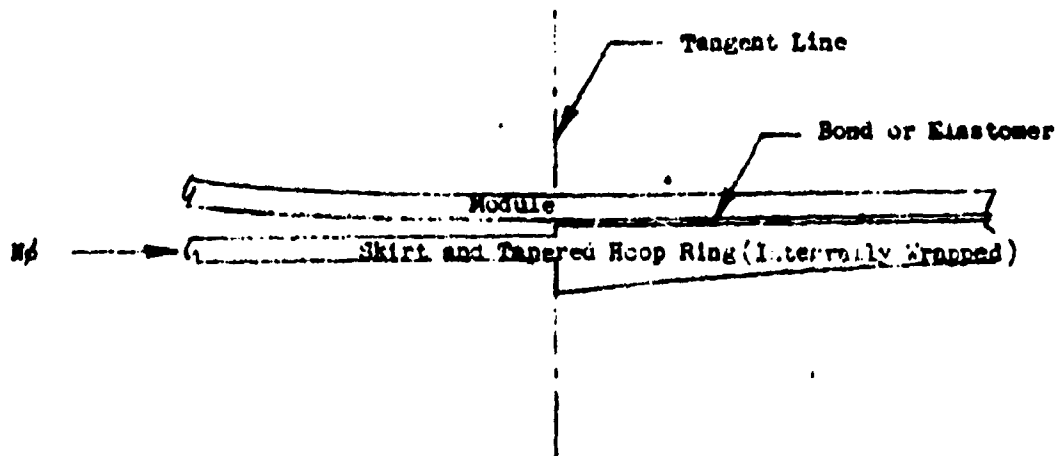
MODULE JOINT (TYPE B)

Center of Dome

FIGURE 6.1.3-2

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HOOP-SKIRT RING

N_p = Longitudinal Force

FIGURE 6.1.3-1

6.1.3.1.3 (Cont'd)

- A. Positive positioning and holding of the foil from winding through cure.
- B. A smooth transition into the joint maintained to prevent bridging or winding material.
- C. Provisions to guarantee that during the cure cycle, the greater coefficient of thermal expansion of the foil is recognized and that steps are taken to minimize the difference.
- D. The foil shall be cleaned and primed in order to provide a bond capable of carrying large shear loads.

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6.2 RECENT STATE-OF-THE-ART DEVELOPMENTS IN THE SHIM JOINT CONCEPT

Building on earlier technology, the Bendix Corp., conducted a study that is considered typical of similar efforts conducted by other sources and represents an advance in the state-of-the-art of shim joint concept development. The information source is identified by reference (b) together with related references (a), and (c) through (i) of paragraph 6.3.

6.2.1 ABSTRACT OF REFERENCE (b)

This report describes a shim joint concept that was developed to improve the efficiency of joints for attaching to composite material structural members. The shim joint concept reinforces the composite material in the region of the joint with thin metallic layers which permits employing a conventional shear pin joint between the composite members and a mating fitting. Design parameters are defined and design data are established. Improved methods for fabricating the reinforced tube ends and improved testing fixtures are developed. An advanced optimization technique has been applied to the design of the shim joints. It is shown that design parameters can be optimized conveniently by the structural synthesis approach in determining the minimum weight configuration. The results indicate that the shim joint concept can be successfully applied to composite members without prohibitive attachment weight penalties.

6.2.1.1 TYPICAL SHIM JOINTS

It has been determined that structural tubes fabricated of composite materials would be lighter than tubes made from more conventional materials such as steel, aluminum, or titanium alloys. However, even though structural members can be made lighter with composite materials than with the more common metal alloys, the weight of reinforcing composite tube ends and joining them to end fittings will impose penalties. As a result, the significant weight saving potential of composite materials may tend to be offset somewhat by the weight penalties

imposed by joining the tubes to end fittings. The design of efficient, lightweight joints between composite tubes and end fittings is, therefore, a necessary element in the development of composite structural components and requires careful application of design criteria and analysis techniques.

The basic geometry of the shim joint is presented in Figure 6.2.1-1. The shim layers are of uniform thickness and constant length in the longitudinal direction. The composite tube end is separated into several layers and bonded to the shim layers by an adhesive. A single circumferential row of conventional shear pins is used to transfer loads from the composite tube, through the shim layers, to the mating part.

The geometry variables shown in Figure 6.2.1-1 are:

a = distance from pin row centerline to tube end

$D_o(D_i)$ = outside (inside) tube diameter

$D_{oj}(D_{ij})$ = outside (inside) tube diameter in attachment area

$D_{op}(D_{ip})$ = outside (inside) pin diameter

l = distance from pin row centerline to back edge of shims

L_j = total length of reinforced attachment area ($L_s + L_t$)

L_r = length of reinforcing ring

L_s = longitudinal length of metallic shim layer ($l + a$)

L_t = wall thickness transition zone

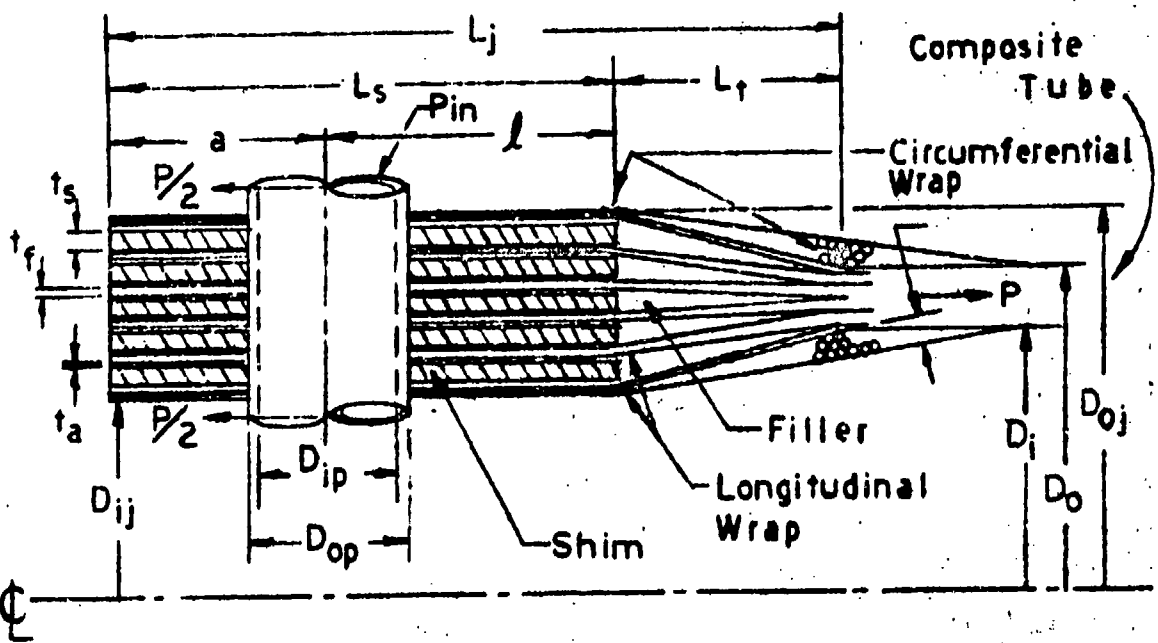
N_o = number of filament layers in tube wall that do not extend into the attachment area

N_p = number of pins along the tube circumference

N_s = number of metallic shim layers

t_a = thickness of the adhesive layer joining the metallic shim to the composite material

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TUBULAR SHIM JOINT DESIGN VARIABLES

Figure 6.2.1-1

t_c = thickness of composite layers which do not extend between shims

t_f = thickness of composite layers between shims

t_r = maximum thickness of the transition length circumferential
reinforcing rings

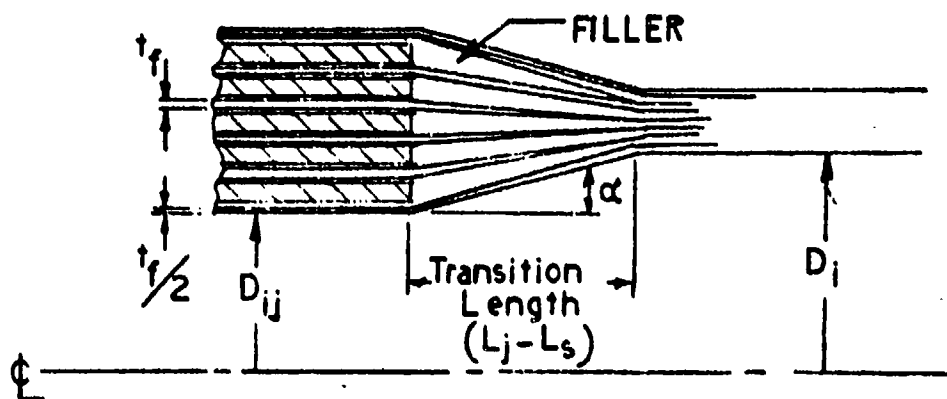
t_s = thickness of metallic shim layers

From a weight standpoint, it is desirable to make the transition length (Figure 6.2.1-2) as short as possible.

6.2.1.2 EFFICIENCY OF THE SHIM JOINT CONCEPT

A comparison was made (Reference[b]) by studying a composite tube having shim joints with tubes of other materials designed to meet the same loading requirement. In Figure 6.2.1-3 the weights of constant strength tubes have been plotted versus tube length. The metal tubes are assumed to have identical strength in tension and compression. Two curves are shown to reflect the different tensile and compressive strengths of 5,000:1,900 fiberglass. Thin wall buckling and column buckling are not considered. The fiberglass tube weights include 0.7 pound to reflect the weight added to both ends of the tube by a minimum weight eleven pin attachment.

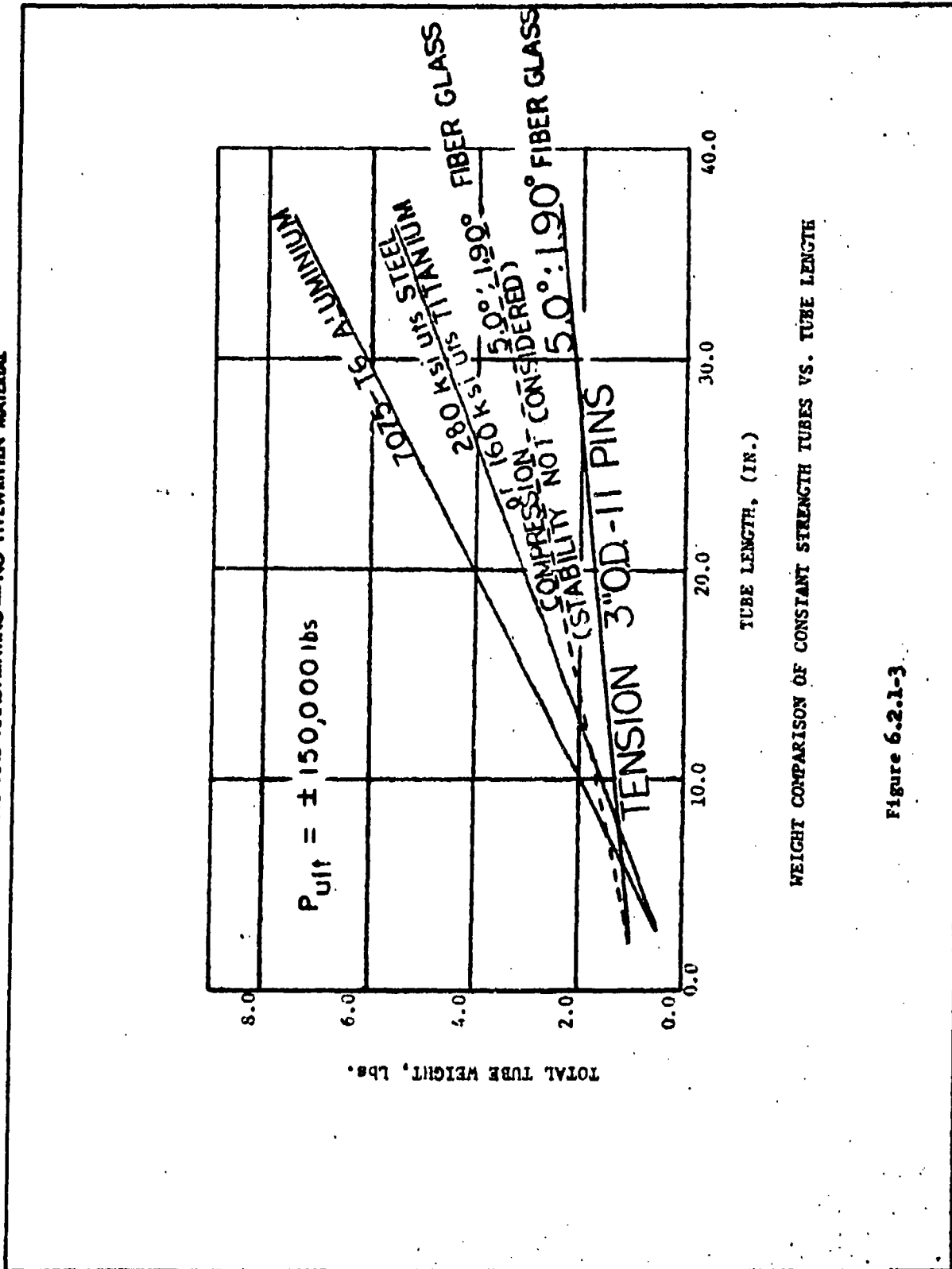
Examination of Figure 6.2.1-3 reveals that for design governed by tensile strength, fiberglass tubes are more efficient than aluminum for tube length of 5.0 inches or larger and lighter than steel or titanium for tube lengths exceeding 7.5 inches. If compressive strength governs the tube design, fiberglass is more efficient than aluminum for lengths greater than 6.5 inches, and lighter than steel or titanium tube lengths exceeding 12.0 inches.



TRANSITION ZONE

Figure 6.2.1-2

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WEIGHT COMPARISON OF CONSTANT STRENGTH TUBES VS. TUBE LENGTH

Figure 6.2.1-3

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6.3 REFERENCES

- a. Thiokol Corporation, Wasatch Division, "Design of a Filament Wound Segmented Motor Case". Technical Report No. AD406679, DDC, April 1-3, 1963, AIAA Launch and Space Vehicle Shell Structures Conference, Palm Springs, Calif.
- b. Cole, B. W., Wong, J. P., and Courtney, A. L., "Development of the Shim Joint Concept for Structural Members", Technical Report No. AFFDL-TR-67-116, August, 1967, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio.
- c. The Bendix Corporation, Products Aerospace Division, "Exploratory Application of Filament Wound Reinforced Plastic for Aircraft Landing Gear", Technical Report No. AFML-TR-66-309, December, 1966, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.
- d. Thiokol Chemical Corporation, Wasatch Division, "Large Segmented Fiberglass Reinforced Plastic Rocket Motor Cases", Report No. ASD-IR-1-150, Vol. I through VIII, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.
- e. Goland, M., and Reissner, E., "The Joint Stresses in Cemented Joints", Journal of Applied Mechanics, March, 1944.
- f. Melcon, M. A., and Hoblit, F. M., "Analysis of Lugs and Shear Pins" Product Engineering, May, 1950 and June, 1953.
- g. "Mechanics of Adhesive Bonded Tap-Type Joints: Survey and Review". Report No. ML-TDR-64-298, 1964, Forest Product Laboratory, U. S. Department of Agriculture, Madison, Wisconsin.
- h. "Manufacturing Methods for Plastic Airframe Structures by Filament Winding", Technical Report No. IR-9-371(1), February, 1967, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.
- i. Ridha, R. A., and Wright, R. N., "Minimum Cost Design of Frames", Journal of Structural Division, Proceedings ASCE, Vol. 93, ST4, August, 1967, Paper No. 5394

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7.0 JOINT CONSIDERATIONS FOR REDUCED SCALE MODEL VEHICLES

7.1 The use of scale model replicas for vehicle structural dynamics studies can provide the designer with valuable information on proposed designs early in their development cycle. By their use, structural modifications and payload changes can be evaluated without expensive full-scale construction and testing, particularly for the large, complex vehicle.

This Section discusses the 1/10 scale structural replica of the Apollo/Saturn V and is intended to provide designers with some insight to the compromises which can dictate deviations from true replica reproduction in the area of missile joints.

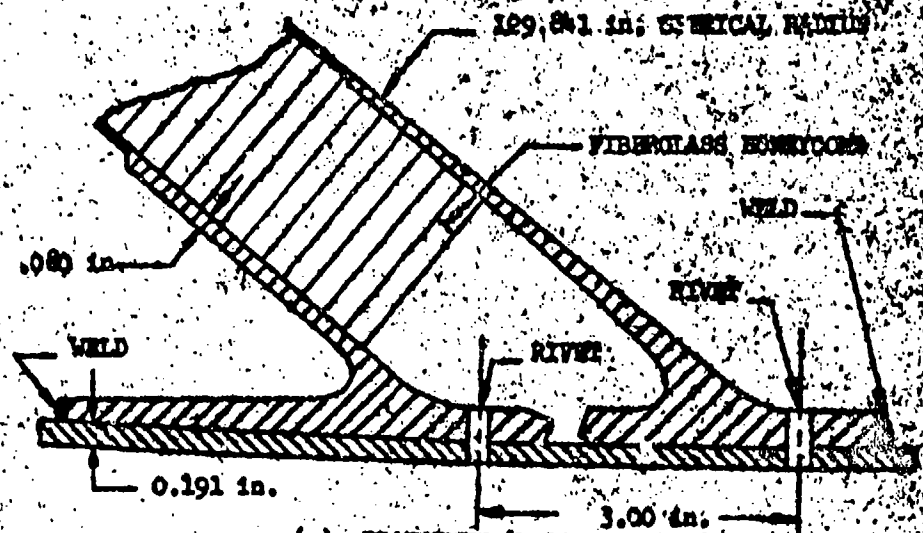
The decision to provide a scaled-down replica of the prototype joint, or to simulate it by its dynamic and dampening equivalent is dictated by the following considerations:

- a. Present fabrication practices and limitations.
- b. Access requirements unique to the model.
- c. Assembly problems created by the size reduction.
- d. Requirement for equivalent dynamic properties.
- e. Fabrication properties of alternative alloys.
- f. Size of scaled-down fastener components.
- g. Economic alternatives of simulation vs scale duplication of the joint.

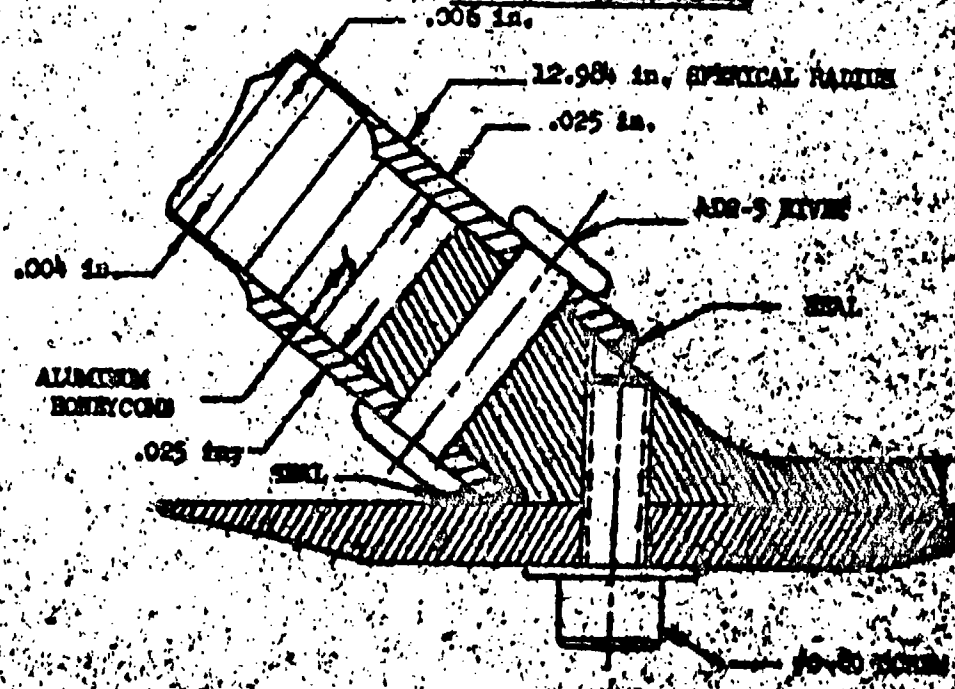
7.1.1 Structural Joints

7.1.2 The joint illustration in Figure 7.1.2-1 is typical of a design variation required to permit assembly of the structural components. This joint depicts the S-IV-B aft-bulkhead-common-bulkhead joint. In full scale (Figure 7.1.2-1a), the fabrication is by rivets and welds. The 1/10 scale model permits the final closure to be effected externally. The bulkhead structure near the joint was

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(a) PROTOTYPE (FULL SCALE)



(b) 3/10 - SCALE MODEL

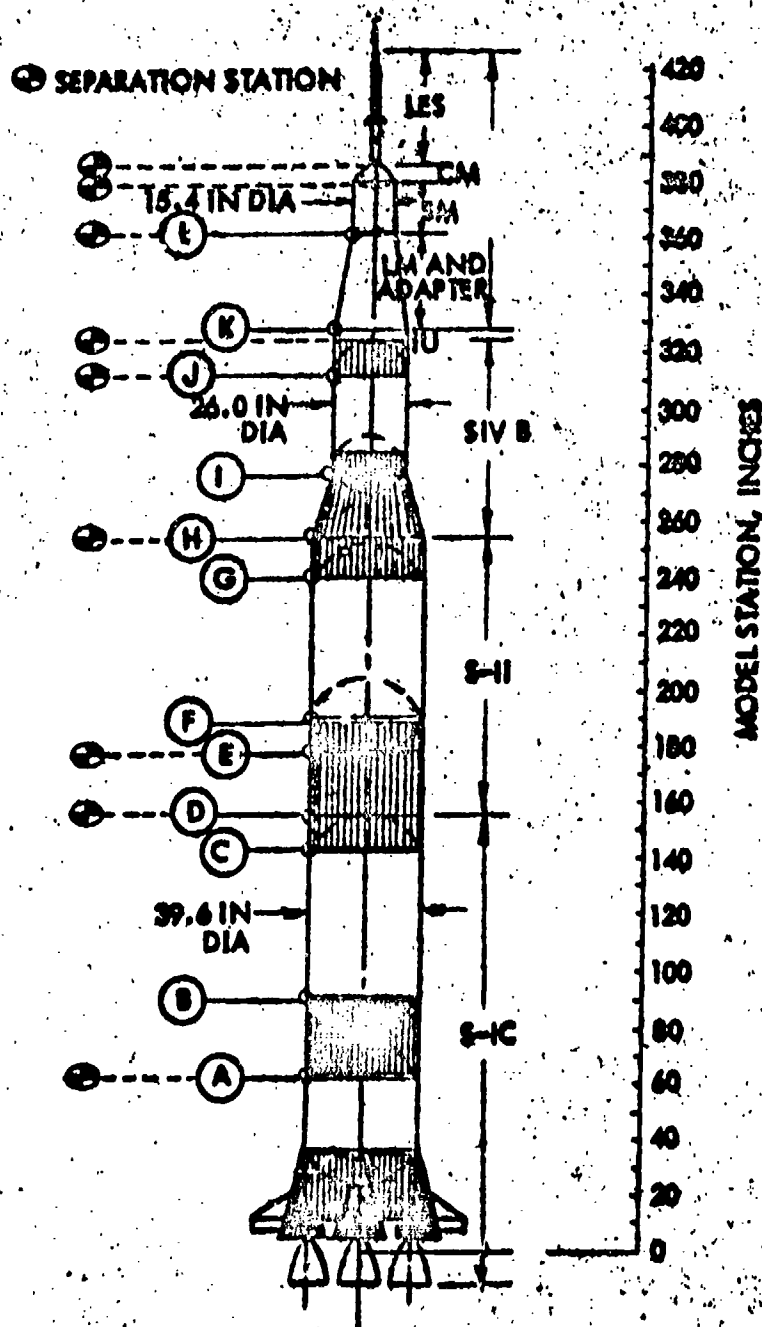
FULL SCALE PROTOTYPE & 3/10 SCALE MODEL GIVE CLOSE RESULTS

FIGURE 1

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FIGURE 1

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SCHEMATIC OF 1/10 - SCALE APOLLO/SATURN V MODEL

FIGURE 7.3.9-1

7.1.2 (Continued)

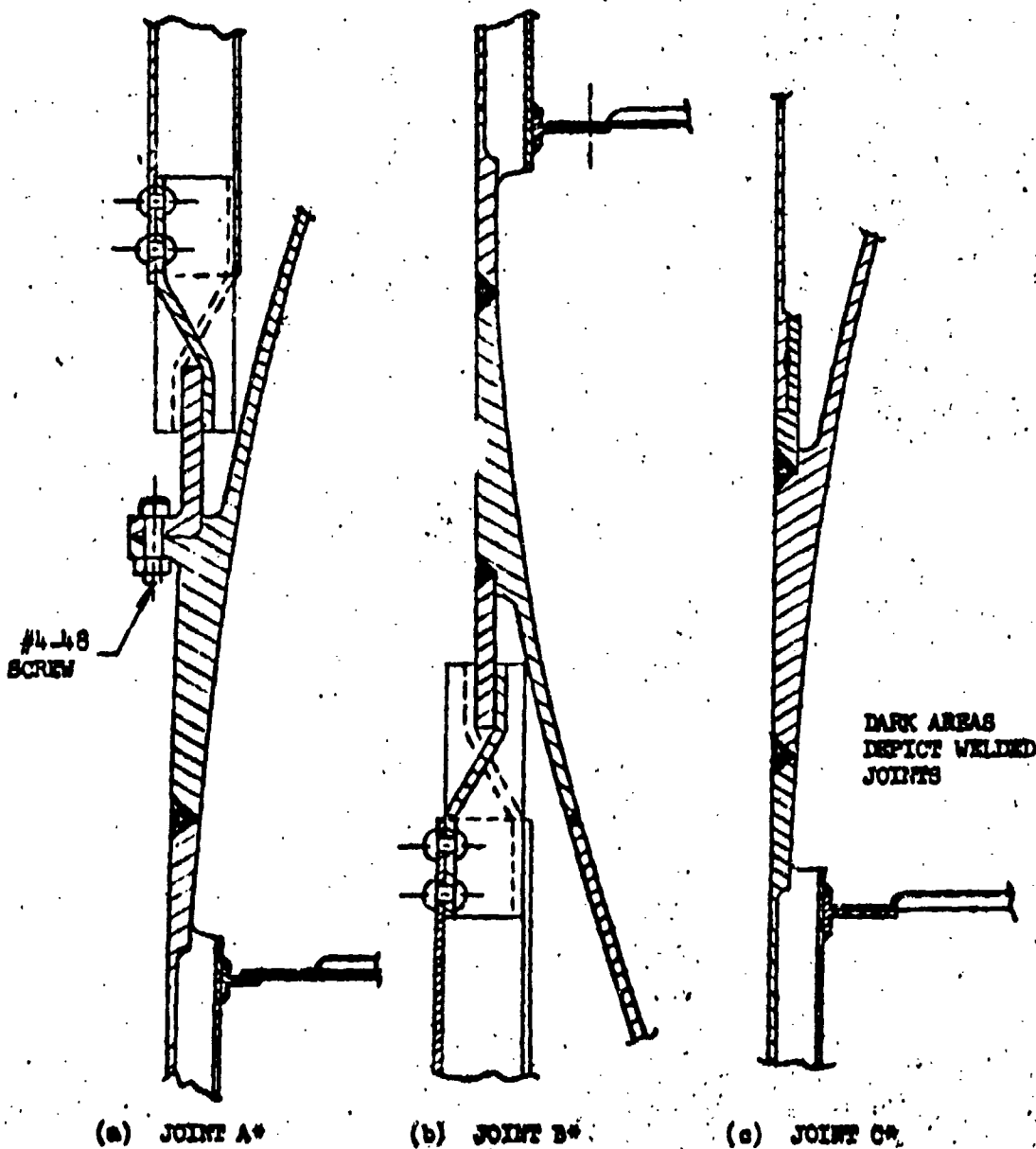
locally modified by adding a relatively heavy adapter ring to which the bulkhead was riveted. This ring was then bolted to the skin from the outside and a bead of sealant compound applied at the intersection of the common bulkhead and the LH₂ tank wall. The resultant joint therefore, is not a true representation of the full-scale component.

7.1.3 An indication of the degree to which the prototype is duplicated is indicated by examination of the joints of Figure 7.1.3-2. The location of the joints detailed in this Figure is shown on Figure 7.1.3-1 by the lettered circles on the left side of the model drawing. The joints of Figure 7.1.3-2 carry corresponding letter identifications.

7.1.3.1 Figure 7.1.3-2a is the junction of the S-IC fuel tank and the intertank section. The fuel-tank upper bulkhead, the fuel tank wall, and the intertank section are joined by a Y-ring assembly. There exists a deviation from replica scaling in that one leg of the Y-ring is attached by a bolted flange to allow access to the intertank interior areas. The intertank Y-ring connection is an unusual joint, made necessary by the complex corrugated intertank skin, and consists of channeled strips attached alternately to the inside and outside surfaces of the Y-ring leg from the corrugated intertank surface.

A similar joint (Figure 7.1.3-2b) is used at the intersection of the lower LOX tank-bulkhead-LOX-tank-wall and intertank structure. This joint, however is closed by a weld rather than by the bolted flange connection. At the junction of the S-IC LOX tank upper bulkhead and tank-wall-forward-skirt interface shown in Figure 7.1.3-2c, a variation was utilized in the model structure. In order to complete the final weld in the joint, the Y-ring was fabricated in two pieces and the shorter leg was spotwelded to the locally thickened forward-skirt skin. The closure was then effected by an external weld. The resultant hardware has the

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Ref Figure 7.1.3-1 and
Paragraph 7.1.3-1

FIGURE 7.1.3-2

7.1.3.1 (Continued)

same basic dimensional properties as would have resulted from direct geometric scaling.

7.1.3-2 The model joints shown in Figures 7.1.3-2d and 7.1.3-2e are scaled duplicates of prototype joints with the exception that the number of fasteners used in the model is less than the number required on the prototype. The fasteners, however, are sized so that the total fastener area was a scaled quantity. The application of replica scaling to the joint of 7.1.3-2d was judged to be the most expedient approach since considerable engineering time would have been required to properly design a more easily manufactured connection with comparable dynamic properties. Further, the scaling laws applicable to a joint of this type are not sufficiently defined to permit evaluation of any alternate design, particularly the effect of the pinned-truss ring frame braces.

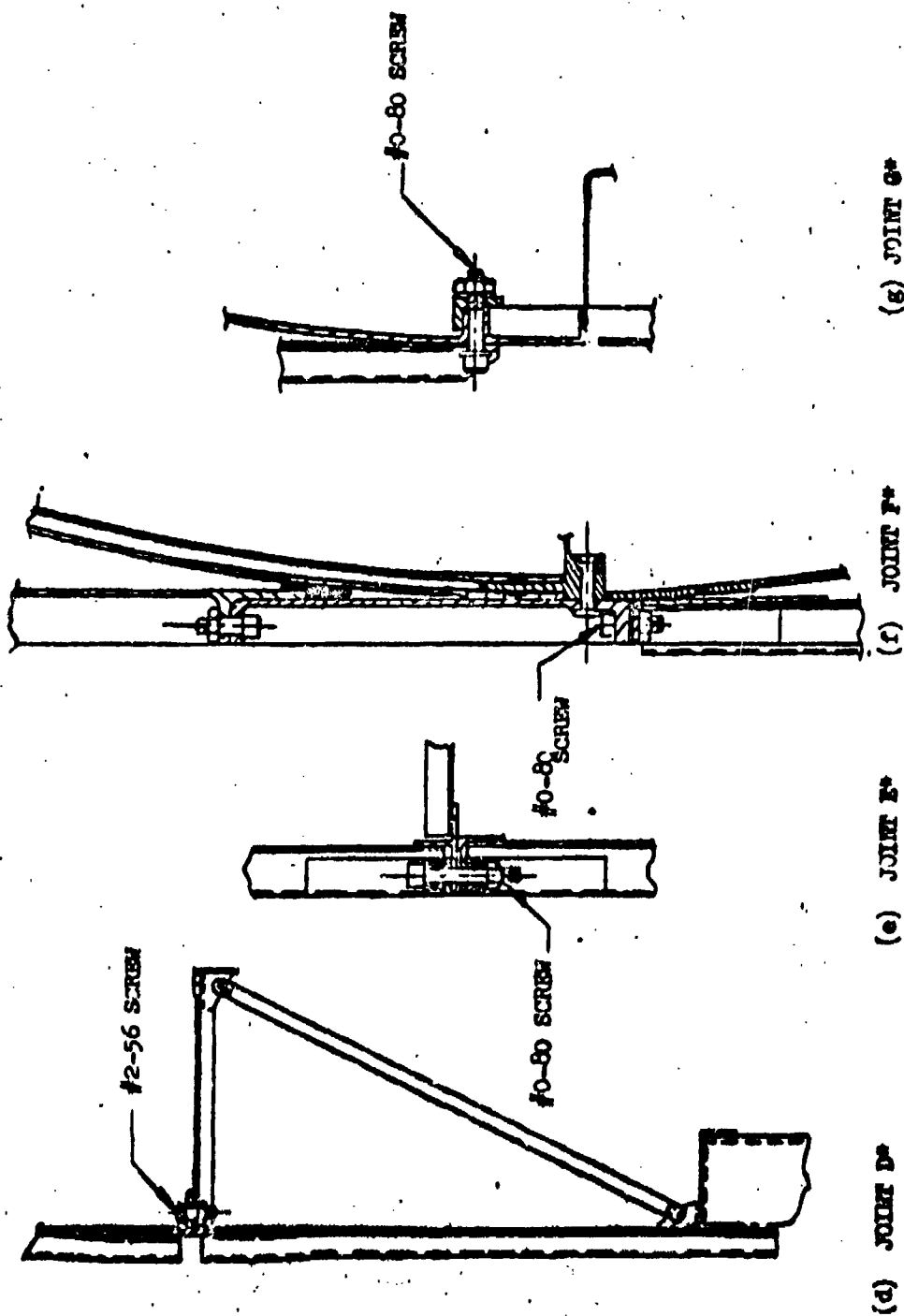
7.1.3-3 The remaining structural joints of Figures 7.1.3-2f through 7.1.3-2l are essentially scaled duplicates of the full-scale structure except for deviations in ring-frame and bulkhead construction dictated by fabrication time and cost considerations. The alternative design approach permitted the use of manufacturing procedures which produced geometrically similar structural components with fewer and less intricate machine processes. The resultant structures have the same structural dynamic properties as the more complex exact miniaturization of the full scale structure.

7.2 Fabrication Problems

7.2.1 Other fabrication problems, not classified as design deviations, include machining processes, metal forming procedures, machine and chemical milling tolerances, fastening methods, and welding techniques. Not only can the solution of these problems dictate the degree to which a given launch vehicle can be reproduced to a specified reduced scale, but they also can be significant factors in

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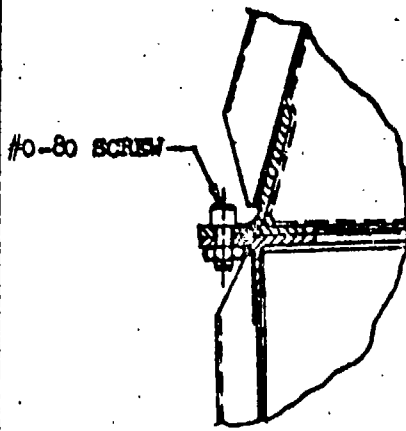
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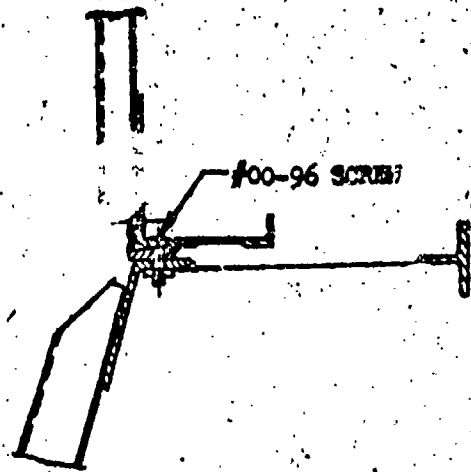
*Ref Figure 7.1.3-1 and
Paragraph 7.1.3-2

FIGURE 7.1.3-2 (Cont.)

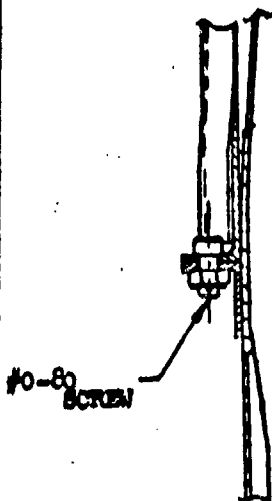
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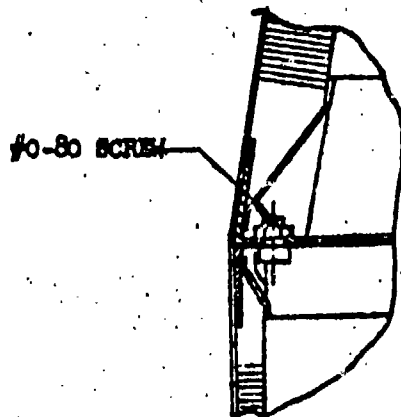
(h) JOINT H*



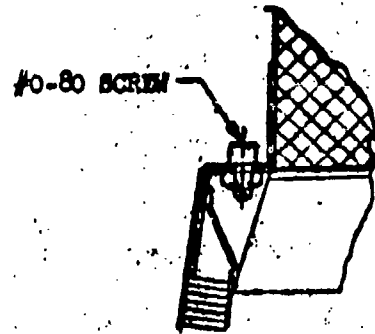
(i) JOINT I*



(j) JOINT J*



(k) JOINT K



(l) JOINT L*

*Ref Figure 7.1.3-1 and Paragraph 7.1.3-3

FIGURE 7.1.3-2 (Cont)

7.2.1 (Continued)

establishing the economic feasibility of acquiring a dynamic model such as the 1/10 scale Apollo/Saturn V. If the resulting fabrication limitations are practical, it may be possible to duplicate the full-scale structure at a predetermined reduced size at less cost than would be needed to simulate the structure by employing corresponding expensive engineering time.

A factor found to be beneficial for fabricating the model joints included methods employed to make the required assembly attachments. The full-scale joints were fabricated with appropriate weldments, bolts, nuts and rivets. Obviously the components of the smaller model must be assembled by other methods because of the impracticability of the reduced scale attachment hardware. There must be a compromise both in type and the number of simulated fasteners. Also, it is generally accepted that whenever an effort is made to approximate the structural dynamic properties of a complex structure, the detail design of the joints and attachment hardware should be conservative with a resulting excessively stiff component since any effort to scale directly the size and number of bolts and rivets would be impractical both from a manufacturing and assembly viewpoint.

In addition, although it is true that there can be some conservative distortion of the joint stiffness properties, there can be little hope of achieving any degree of success in reproducing desired damping characteristics when rivets and bolts are replaced by spot welds. Generally, bolted joints can be represented by using convenient, commercially available fasteners, such as O-80 screws, a lesser number of fasteners being used, the number of which is determined from the correctly scaled fastener area. This design approximates the proper stiffness and damping.

7.3 Conclusions

7.3.1 Replica scaling of the main load carrying structural joints, which together with other structural components, necessitated an extension of the state-of-the-art in fabrication techniques, was employed and resulted in a model which duplicates the full-scale structure to a high degree. Extreme full scale design details, such as joint reproduction, were duplicated in the fabrication of the 1/10 scale model.

A careful analysis of the prototype structural details was required to ascertain the practical and economic feasibility of duplicating component hardware to the chosen scale factor. Where model joint design dictated sizes too small to be duplicated, an acceptable design required that only the correct mass and stiffness distributions be retained in the model. Some joints could not be adequately defined by the most rigorous present-day dimensional analysis and therefore were built as scaled duplicates of the full scale members. If the joints were of secondary importance from a dynamic viewpoint, they were a scaled replica because they required less expenditure of effort with duplicate fabrication than with dynamic simulation. All substitutions were carefully considered, however, lest their inclusion degrade the usefulness of the total structure through either introduction of misleading response data or the suppression of critical responses.

With proper care in the selection of the scale factor and methods of manufacture and with judicious evaluation of deviations from direct scaled duplication, the replica models are considered technically and economically feasible for studies of the structural dynamic characteristics of large complex vehicles.

An in-depth description of the project is available in Reference 1, from which the information presented herein was derived.

REFERENCES

1. D2-11165 - Structural Development Note #9 - Sandwich Material, Rev. 3-31-58
Presents design criteria and allowables for structural design
and stress analysis of sandwich components for aircraft application.
Provides background in this type of construction for designers.
2. NASA TN D-4138 - Design and Fabrication Considerations for a 1/10 - Scale
(ASTIC 056062)
Replica Model of the Appolo/Saturn V.

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8.0 DOCUMENT OPTION FOR FUTURE WORK

8.1 Originally planned as a one year effort, the joint study was reduced to six months due to budgetary and manpower requirements. While it is recognized that a great deal more information might be included in this document, it is felt that in its present form it provides a useful tool to the designer faced with the problem of missile or space vehicle joint design.

Should a decision be forthcoming to continue the effort, the immediate direction taken will be to investigate raceway and other non-structural joints. Follow-on effort will be a report on the latest state-of-the-art in joint design concepts, missile carrier interface joints, joint fastener hardware, plumbing and electrical joint interfaces and recent advances in materials and process technology as applied to missile joints.

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SHEET 142

| REVISIONS | | | |
|-----------|--|----------------------|-------------------------------------|
| LTR | DESCRIPTION | DATE | |
| A | <p>Renumbered sheets and made the following changes to accomplish a complete revision:</p> <p>Revised sheets: 2, 4, 6, 7, 8, 13, 15, 20, 21, 23, 26, 27, 29, 30, 31, 34, 35, 36, 40, 41, 44, 62, 63, 69, 75, 77, 83, 87, 91 through 104, 107, 109, 113, 115, 117, 118, 119, 126</p> <p>Added new sheets: 9, 10, 11, 12, 14, 16, 17, 18, 19, 22, 23, 24, 39, 45 thru 58</p> | 10/11/77 10/11/77 | W. J. [Signature] |
| B | <p>Made the following changes to accomplish a complete revision:</p> <p>Revised sheets: 1, 2, 4, 6 thru 10, 12 thru 16, 18 thru 24, 27 thru 42, 44 thru 60, 62, 63, 64, 66, 67, 69 thru 73, 75, 77, 78, 79, 81 thru 85, 87, 89, 91 thru 101, 103 thru 107, 109, 110, 114, 111, 113, 116 thru 120, 122, 123, 125 thru 143.</p> <p>Deleted sheets: 144 thru 167</p> <p>Added date and approval signatures omitted on release of Revision A</p> | 12-10-80 12-10-80 | W. J. [Signature] J. [Signature] |